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WIRELESS SENSOR NETWORK-DRIVEN SOLUTION FOR MONITORING AND CONTROLLING INDUSTRIAL POLLUTION

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Abstract— Environmental conditions exert a significant influence on our well-being, comfort, and productivity. The present condition of air quality control in nearly all manufacturing industries in our nation relies on sampling once or a few times a day. This implies a lack of information about the time distribution of the intensity of polluted materials throughout the day. This document advocates for an industrial air pollution monitoring system utilizing a wireless sensor network that allows sensor data to be delivered within time constraints, enabling timely observations or actions. Wireless Sensor networks provide the ability to collect precise and consistent data, facilitating early warnings and prompt coordinated responses to potential threats of natural disasters and environmental changes. Broad synchronization is a crucial requirement for optimal information regarding various types of pollution. The sensor nodes detect data related to pollution parameters and transmit it to a sink to create an overview of the pollution state. This paper analyzes the use of wireless sensor networks for pollution control and monitoring. Obtaining these accurate real-time results on-site allows regulatory agencies to take necessary action whenever pollution occurs.

The analysis focuses on six substances, referred to as criteria air pollutants ozone, particulate matter, sulfur oxides, nitrogen oxides, carbon monoxide, and lead. The sensors autonomously organize themselves in a radio network using a routing algorithm, monitoring the area to measure gas levels in the air and transmitting the data to a central node, sometimes called a pollution server or base station (interfaced with coordinator), or sink node, that collects data from all sensors. This work is backed by the Technology for Urban Liveability Program at the University of Technology Sydney and by the Vingroup Science and Technology Scholarship (VSTS) Program for Overseas Study for Master's and Doctoral Degrees. Gratitude

is extended for discussions with Matthew Riley, Merched Azzi, and Hiep Duc from the NSW Department of Planning, Industry, and Environment (Climate and Atmospheric Science). Armed with results from the data acquisition system, the regulatory agent must implement a series of decisions based on the final statistics. Real-time analysis of data from experiments yielded promising results from two sensor nodes over a 24-hour period. Implementing this system will mitigate human health effects of industrial air pollutants and potential damage to other aspects of the environment.
Keywords: Wireless sensor networks; air pollution; monitoring system; air quality; sensors.

I. INTRODUCTION

Pollution refers to the introduction of chemical substances and unwanted energy into the environment, causing unfavorable variations in the natural system. There are various types of pollution such as air pollution, water pollution, noise pollution, soil pollution, etc. This paper focuses on air pollution, water pollution, and noise pollution, examining the use of sensors to control these environmental issues[1]. The Internet of Things (IoT) is a system of interconnected computing devices, machines, objects, or people with unique identifiers (UIDs) and the ability to transfer data over a network without human-to-human or human-to-computer interaction. Big data involves analyzing large or complex data sets that traditional software cannot handle[3].

In the pursuit of progress, humanity has overlooked sustainability-[5], becoming a major contributor to rising pollution levels affecting the world's air and all other living organisms. Pollution is categorized into air, water, and noise pollution, reaching levels that harm not only the environment but also ourselves.

An IoT-based pollution monitoring system includes sensors connected to devices equipped with WLAN connectors, sending readings to a Thing Speak cloud. The scope of this work involves an AI model to predict pollution levels, a subset of predictive modelling[2]. As the emission of toxic gases increases daily, controlling pollution from industries, vehicles, and other sources becomes challenging. This system proposes a practical pollution monitoring framework for observing behavior in a specific area and identifying pollution characteristics[4].

The proposed system focuses on monitoring pollution with the integration of the Internet of Things and wireless sensor networks, calculating Air Quality Index (AQI), Water Quality Index (WQI), and Land Quality Index (LQI)[4].

The system aims to safeguard natural resources for public safety by continuously monitoring air quality, soil status, and controlling pollution [4], thereby increasing public safety. Additionally, big data helps maintain volumes of air, water, land moisture, and temperature contents. Wireless sensor networks (WSN) were initially developed for military applications and are now used in various industrial and civilian areas, including pollution monitoring and control.

Objectives of the system:

Pollution is defined as the presence of particles that disrupt natural processes and have adverse health effects. Pollution is spreading due to industrialization and automation, impacting human health, especially in regions lacking monitoring systems.

Recent research shows a high correlation between atmospheric pollutants and diseases like asthma. Air and water pollution are global concerns, and the World Health Organization (WHO) has established guidelines to limit specific gases like O3, NO2, and SO2.

Air Quality Index and Water Quality Index measurements are primarily done at surface stations, which are accurate but face challenges in infrastructure, operational complexity, and high costs.

Monitoring and assessment are terms often used interchangeably. Industrial quality assessment evaluates industrial quality against pollution control board standards. Due to the complexity of factors, there are significant variations between industries.

Response to industrial impacts varies widely, and designing an Industrial IoT-based machine control and monitoring system is essential. Surveillance is crucial for security in various settings. Building a robust system for continuous evaluation and control of industrial pollution is necessary for a healthy environment and worker well-being.

II. LITERATURE SURVEY

Golla Keshav Aditya (2015) et al presents that air and noise pollution are the growing hazardous issues. It is necessary to monitor air quality and keep it under control for a better future and healthy living for all. Here we propose an air quality as well as sound pollution monitoring system that allows us to monitor and check live air quality as well as sound pollution in particular areas through IoT. The system uses air sensors to detect the presence of harmful gases/compounds in the air and constantly transmit this data to a microcontroller[3]. Also, the system keeps measuring sound level and reports it to the online server over IoT. The sensors interact with the microcontroller which processes this data and transmits it over the internet. This allows authorities to monitor air pollution in different areas and take action against it. Also, authorities can keep a watch on the noise pollution near schools, hospitals, and no honking areas, and if the system detects air quality and noise issues, it alerts authorities so they can take measures to control the issue.

A.R. Al-Ali (2016) et al proposed the level of pollution is increasing rapidly due to factors like industries, urbanization, increasing in population, vehicle use which can affect human health. IoT Based Air Pollution Monitoring System is used to monitor the Air Quality over a web server using the Internet. It will trigger an alarm when the air quality goes down beyond a certain level, meaning when there are sufficient amounts of harmful gases present in the air like CO2, smoke, alcohol, benzene, NH3, and NOx. It will show the air quality in PPM on the LCD and as well as on a webpage so that air pollution can be monitored very easily[6].

Yunping Chen (2017) et al developed an air and noise pollution monitoring device is a great step towards a healthy livelihood. With the help of this device, not only the municipal authorities but even the common people can participate in the process of controlling pollution and ensure a safe environment. This automatic device, once installed, is capable of continuously tracking the pollution level and analyzing the detected information. The most highlighting feature of this device is that the output is represented in digital as well as analog format with the help of a simple mobile application which is usable on all Android devices like smartphones, tablets, PDAs, etc. The device itself is very eco-friendly and does not harm the environment in any way.

Khaled Bashir Shaban (2016) et al monitor the Air Quality over a web server using the internet and will trigger an alarm when the air quality goes down beyond a certain level, meaning when there are sufficient amounts of harmful gases present in the air like CO2, smoke, alcohol, benzene, and NH3[5]. It will show the air quality in PPM on the LCD and as well as on a webpage so that we can monitor it very easily. We have used MQ135 sensor which is the best choice for monitoring Air Quality as it can detect most harmful gases and can measure their amount accurately[5]. In this IoT project, you can monitor the pollution level from anywhere using your computer or mobile.

Ahmed Boubrima (2017) et al monitor the Air Quality over a web server using the internet and will trigger an alarm when the air quality goes down beyond a certain level, meaning when there are sufficient amounts of harmful gases are present in the air like CO2, smoke, alcohol[6], benzene, and NH3. It will show the air quality in PPM on the LCD and as well as on a webpage so that we can monitor it very easily. Ke Hu (2016) et al suggested the pollution of air and sound is increasing abruptly. To bring it under control its monitoring is majorly recommended. To overcome this issue, we are introducing a system through which the level of sound and the existence of the harmful gases in the surroundings can be detected[7]. The growing pollution at such an alarming rate has started creating trouble for the living beings, may it be high decibels or toxic gases present in the environment leaves a harmful effect on human’s health and thus needs special attention.

AR. Al-Ali (2016) et al implementation for the Internet of Things is used for monitoring atmospheric conditions of the environment like air pollution and sound pollution[6]. This paper presents a conceptual architecture for a versatile, flexible, and cost-efficient for monitoring the air and sound quality of a particular site. In the description of this integrated network architecture and the connected mechanisms for reliable and accurate measurement of parameters by sensors and the transfer of information or data are done with the help of the internet [7]. This system is able to provide a mechanism for the operations of the devices to do better in the monitoring stage. This monitored data can be obtained from a remote location without actually visiting it due to the access to the internet. The framework of this monitoring system is based on the combination or collaboration of effective distributed sensing units and information systems for data composition. The role of IoT is the new concept used in air and sound pollution measurement, which allows data access from remote locations[7].

Jose Antonio Sanchez (2015) et al devised a solution for overseeing air pollution levels in the environment. The proposal involves the Internet of Things (IoT) technology, which is an innovative approach to design and configure systems and services based on transformative changes. Here, the sensing devices are linked to the computing system to observe the fluctuation of parameters from their normal levels[8]. This model is suitable for any infrastructural environment that requires continuous monitoring, controlling, and behavior analysis. The operational performance of the suggested model is assessed using prototype implementation, comprising Raspberry PI and sensor devices[8].

Ashfaqur Rahman (2017) et al suggests an approach to monitor air pollution parameters using the Raspberry-Pi. The system is developed using the Python coding language. The monitored values can be accessed from the Internet of Things platform. The air pollution parameters [9] are obtained from affordable gas sensors. The parameters include concentrations of smoke, carbon monoxide, and nitrogen dioxide, temperature, and humidity. Additionally, an alarm is triggered to indicate high concentrations of emissions. This serves as a warning to the authorities about the air pollution rate. A graph is generated using the monitored values using the ThingSpeak platform.

Jose M. Cecilia (2018) et al monitors the air quality in industrial and urban areas. The proposed framework incorporates a set of gas sensors (CO and NO2) that are positioned on masses and the structure of an IoT (Internet of Things) along with a dominant server to support both short-range real-time incident management and continuous deliberate planning. In this, the Arduino platform is utilized to communicate the data simply and quickly. WSN (Wireless Sensor Network) serves as the transceiver. This offers a real-time low-rate monitoring system, utilizing low-rate, low-information rate, and minimal control wireless communication technology[9].

III. EXISTING SYSTEM

The current system lacks internet connectivity for inter-connected devices. To meet the requirements of an effective monitoring system, our project establishes a network known as the Internet of Things (IoT), connecting sensing devices. Air pollution is not only a concern for developing nations but also impacts medical matters. The profound effects of air pollution on health are significant, given the diverse sources, each with its unique impact. The chemicals contribute to various human and environmental health issues, exacerbating the effects of air pollution on both the environment and human health. To address this issue, a Wireless Sensor Network (WSN) system is proposed [9].

The suggested framework consists of a Mobile-DAQ unit and a fixed Internet-Enabled pollution monitoring System. The Mobile-DAQ unit includes a single-chip microcontroller, air pollution sensors, and a GPS device. The Pollution-Server is a high-end personal computer acting as an application server with internet connectivity. The Mobile-DAQ unit collects levels of air pollutants (CO, NO2, and SO2) [8] and packages them with GPS physical coordinates, time, and date. The intention is to transmit this data to the Pollution-Server via a Zigbee device. The Pollution-Server is connected to Google Maps to display the equipment's location. It can also connect to a database server to store pollution data for future use by various users, such as environmental protection agencies, vehicle registration authorities, tourists, and insurance companies[10].

The SIM900A is an ultra-compact and reliable wireless module that provides a complete Dual-band GSM/GPRS solution. With an industry-standard interface, the SIM900A delivers GSM/GPRS 900/1800MHz performance for voice, SMS, Data, and Fax in a small form factor with low power consumption. This module, measuring 24mmx24mmx3mm, can fit into various space requirements in user applications[9], especially those with slim and compact design demands.

The proposed system integrates wireless embedded computing with the Internet of Things, connecting sensors to an embedded system and allowing data from these sensors to travel over the Internet. The model monitors parameters such as air quality, noise levels, temperature, humidity, and light[9]. The model utilizes a microcontroller (ATMEGA328) mounted on an Arduino Uno board, along with five sensors: MQ-7 for detecting carbon monoxide, M213 for noise levels, LM35 for temperature, SY-HS220 for humidity, and an LDR sensor for measuring light intensity. The values are displayed on the LCD display.

Drawbacks:
• High maintenance expenses
• Lack of device connectivity
• Limited expertise
• Insufficient public safety measures
• Slow processing
• Highly observable
• Inadequate measurement readings for air and water quality

IV. PROPOSED SYSTEM

The project aims to develop an air pollution monitoring system that can be implemented in a specific locality, aiming to improve upon earlier systems by overcoming previous drawbacks. This enhancement includes the development of an Android app accessible to the public, providing real-time updates on pollution levels in their region. It incorporates Arduino integrated with individual gas sensors[11], such as carbon monoxide, ammonia, particulate matter, humidity, and smoke, each measuring the concentration of gases separately. The collected data is regularly uploaded to the cloud using the Adafruit IO platform, with the Arduino and cloud connected through an Ethernet shield. Adafruit IO is utilized for pictorial or graphical representation of values[10].

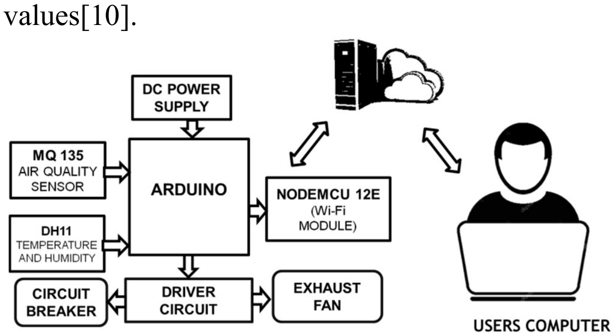

Figure. ***Pollution Monitoring Using Raspberry Pi***

A specific time control is assigned based on the standard level of each measured gas, and the results are viewed in the Android application. The system's architecture focuses on air pollution monitoring and awareness creation. The concentration levels of each gas can be displayed as both a graph and in numerical format. The air quality index is calculated based on these values, determining the air quality's nature in that area, which is also shown through the app. Health effects corresponding to the air quality are displayed to raise awareness. Users can also access temperature and weather information for that region. The system ensures users receive location-specific and relevant data, allowing them to stay informed about the current air pollution status.

The proposed system primarily employs the Internet of Things (IoT) to connect smart devices (embedded hardware devices) and leverages the OSI layered architecture. It introduces a set of Air Quality and Water Quality Monitoring Sensor nodes used to measure air pollution concentrations. These sensors are connected to an embedded platform with network connectivity, forming a global network of interconnected devices[12].

The system aims to design a robust monitoring system for real-time emission levels and temperatures in industries and designated areas[5]. Data is stored and analyzed in the cloud using the Internet of Things. Various sensors, including temperature, DHT, MQ-2, MQ-6, and dust sensors, measure parameters such as temperature, gas, and dust. The system utilizes a PIC microcontroller with Reduced Instruction Set Computing (RISC) for program execution, reducing complexity[11].

DHT22 Sensor

This DHT22 is a temperature & a humidity sensor with a digital signal output. It provides high stability and reliability. It consists of a Negative temperature coefficient temperature measuring component and a resistive type humidity measurement component. It can be connected to a microcontroller and offers quick, anti-interference ability and cost-effectiveness[11].

MQ-2 Sensor

A carbon monoxide analyzer or CO analyzer is a device that detects the presence of the carbon monoxide gas in order to prevent carbon monoxide poisoning. The circuit setup consists of analyzer head connected to an amplifying unit. A number of supporting resistances are used to avoid voltage drop across the circuit. Resistance value of MQ-2 is difference to various kinds and various concentration gases. So, when using these components, sensitivity adjustment is necessary[12].

It is recommended that calibrating the detector for 200ppm CO in air and using Load resistance of about 10KΩ (5KΩ to 47 KΩ) increases circuit efficiency.

MQ-6 Sensor

The MQ-6 Sensor can detect the small particles like cigarette smoke and it can distinguish small particles like smoke from large house dust by pulse pattern of signal output. It is used for detection of dust in the air, indoor air quality monitoring. The features are compact size and light weight (about W59x H46x D18 mm, 20g). It works on the principle of PWM (pulse width modulation) output (Low pulse output) [11].

Liquid Crystal Display (LCD)

A liquid-crystal display (LCD) is a flat panel display or other electronically modulated optical device that uses the light modulating properties of liquid crystals. Liquid crystals do of the code significantly. WIFI module ESP8266 is used to store the data in the cloud [12], which is flexible and easy to connect and it is connected through the hotspot. The data can be viewed in any browser including smart phones by logging in using the credentials.

ADVANTAGES OF PROPOSED SYSTEM

- High-quality sensors and programming
- Interconnected with the internet (IoT)
- Data storage in "Big Data"
- Enhanced safety with no defects
- Cost savings
- Time efficiency
- Report generation for department progress completion

V. METHODOLOGY

The air and noise pollution monitoring system incorporates Arduino and sensors. Arduino, also recognized as the brain of the device, is initially supplied with a 5V power source. Sensors feed data to Arduino, and if air pollution surpasses the programmed limit, the output is analog[11], signaling elevated air pollution on the output panel. Simultaneously, the buzzer alerts with noise pollution exceeding the set limit. Data from air and sound sensors are transmitted to the Wi-Fi module connected to the microcontroller board's 3.3 V pin.

Need of WSN for Pollution Control

With the rapid growth of industries, the problem of pollution becomes a key concern for healthy life style. Raw readings of pollutant can be obtained by monitoring and these readings can be analyzed and interpreted to know the status of pollution. Wireless sensor networks are useful to understand the state of pollution in a particular area. In critical situation, there is a need to provide safety guidelines and a alarm which can be possible with application of Wireless sensor and actor networks[12].

WSN and Air Pollution

Wireless sensors deployed in large numbers can monitor air pollution around a region of interest, especially near industries and vehicle traffic. Real-time data from WSN is valuable for alerting severe air quality changes, enabling preventive actions to control air pollution more effectively than traditional data loggers[13].

WSN and Water Pollution

As industrialization progresses, water resources are increasingly threatened by pollution. WSN helps in the automatic monitoring and real-time control of wastewater treatment[13]. It monitors water characteristics such as temperature, pH, and turbidity, allowing for efficient and timely action to protect water resources.

WSN and Noise Pollution

Noise pollution poses a significant challenge in today's scenario, negatively impacting health and quality of life. WSN, with its sensor nodes[14], can monitor noise levels in specific areas, contributing to noise pollution control. These nodes operate unattended to gather noise pollution readings and can also assist in traffic management based on road traffic noise.

Power Supply

Various types of power supply exist, designed to convert AC mains electricity to a suitable low voltage supply for electronic circuits and devices. A power supply comprises blocks performing specific functions, including a step-down transformer, rectifier circuit, and voltage regulator. A bridge rectifier and voltage regulator ensure stable and regulated DC voltage output.

Node MCU

The NodeMCU is an open-source firmware and development kit for prototyping IoT products with a few Lua script lines. It utilizes the ESP8266 module, a self-contained SOC with integrated TCP/IP protocol stack, offering Wi-Fi connectivity to microcontrollers.

ESP 8266

The ESP8266 WiFi Module provides access to Wi-Fi networks for microcontrollers. It can host an application or offload Wi-Fi networking functions from another application processor. With an AT command set firmware, it comes pre-programmed and features a vast community for support.

Features:

- ✓ Open-source
- ✓ Interactive
- ✓ Programmable
- ✓ Low cost
- ✓ Simple
- ✓ Smart
- ✓ WI-FI enabled

ARDUINO

Arduino is an open-source platform used for building electronics projects. Arduino consists of both a physical programmable circuit board (often referred to as a microcontroller)and a piece of software, or IDE (Integrated Development Environment) that runs on your computer, used to write and upload computer code to the physical board. The Arduino platform has become quite popular with people just starting out with electronics, and for good reason. Unlike most previous programmable circuit boards[14], the Arduino does not need a separate piece of hardware (called a programmer) in order to load new code onto the board – you can simply use a USB cable. Additionally, the Arduino IDE uses a simplified version of C++, making it easier to learn to program. Finally, Arduino provides a standard form factor that breaks out the functions of the micro-controller into a more accessible package.

Figure: ***Arduino Uno***

Microcontroller	ATmega428
OperatingVoltage	5V
InputVoltage(recommended)	7-12V
InputVoltage (limits)	6-20V
Digital I/O Pins	14(ofwhich 6providePWM output)
AnalogInputPins	6
DCCurrent perI/O Pin	40 Ma
DCCurrent for4.4V Pin	50 Ma
FlashMemory	42KB(ATmega428) of which 0.5 KB used by boot loader
SRAM	2 KB (ATmega428)
EEPROM	1 KB (ATmega428)
ClockSpeed	16 MHz

Table: Arduino Summary

Hardware System Architecture Diagram.

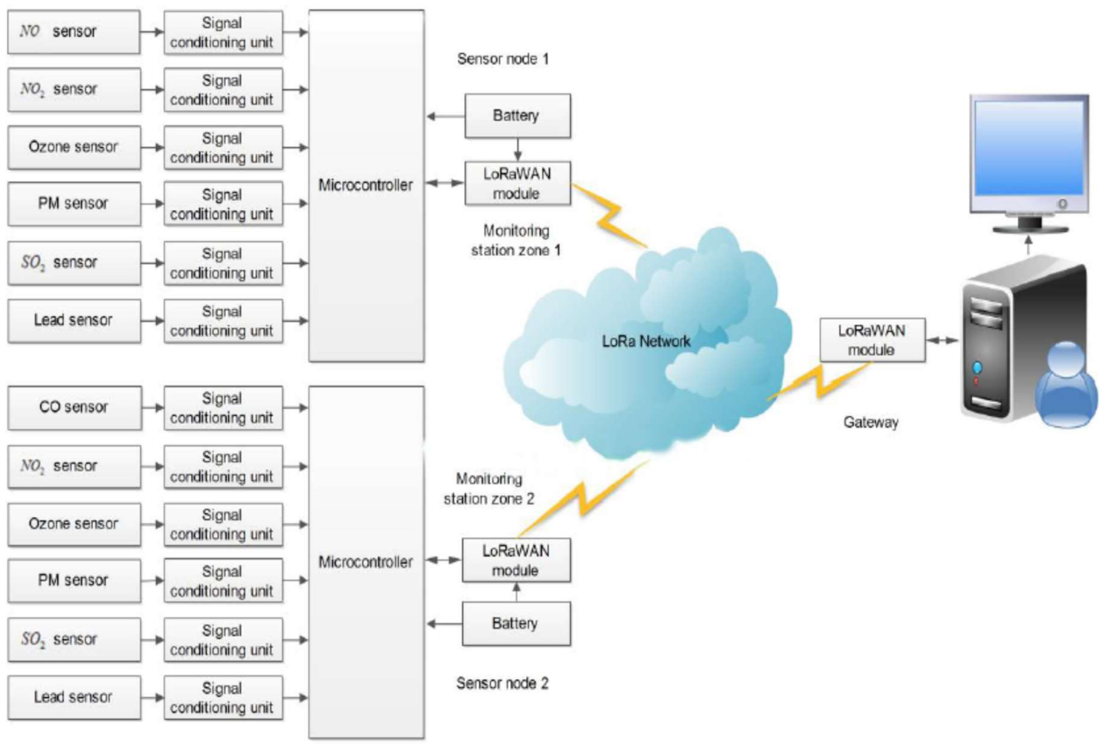

Figure. Hardware Architecture System

Sensor Layout System Architecture Diagram

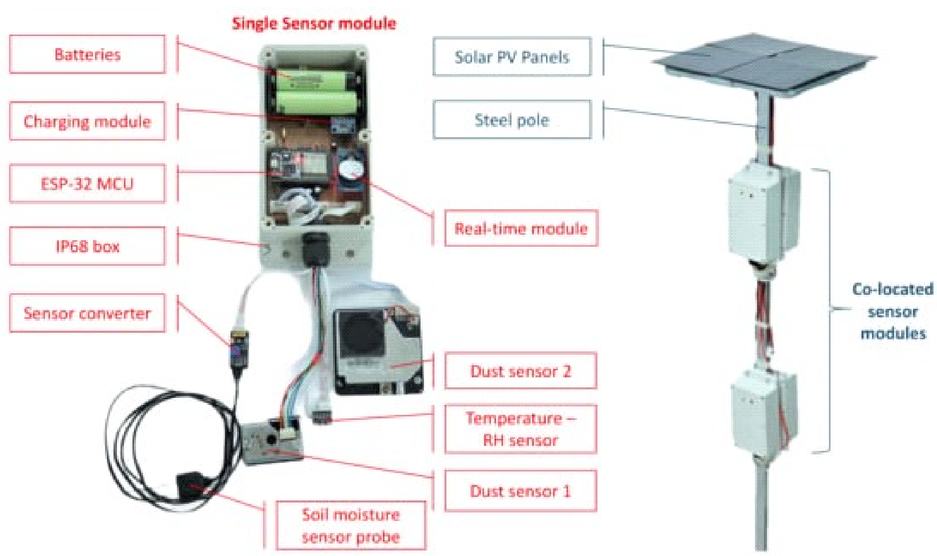

Figure.Sensor Layout of System

Block Diagram

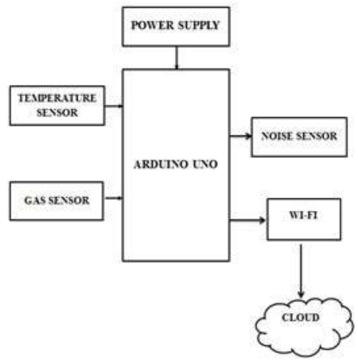

*Figure: **IoT based Pollution Monitoring System***

Block diagram

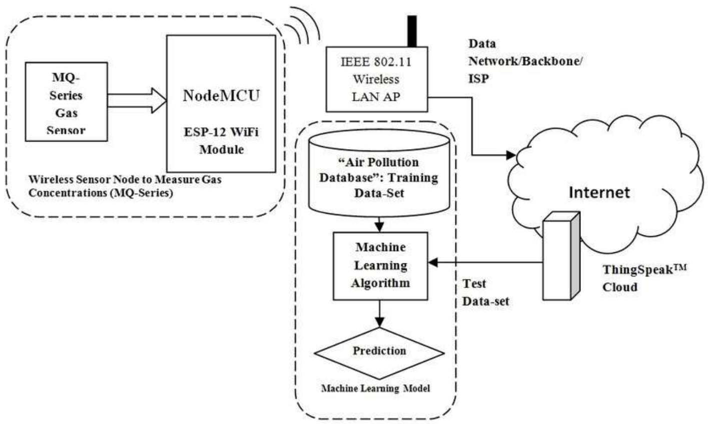

*Figure: **IoT based Air pollution Monitoring System***

Block Diagram

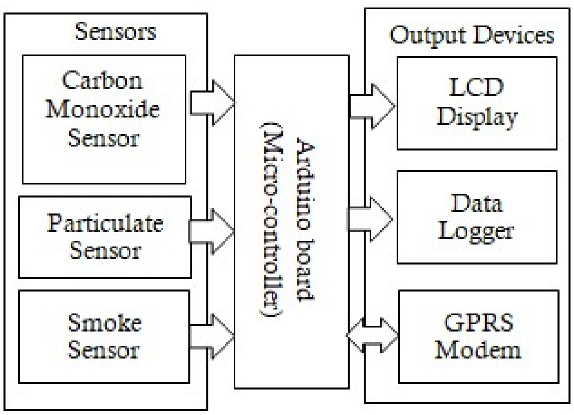

*Figure: **Pollution Quality Monitoring System***

VI. IMPLEMENTATION

Implementation is the stage wherein systems personnel validate and deploy new equipment, instruct users, install the novel application, and generate any requisite data files for its utilization. This phase is less inventive than system design. Depending on the organization's size involved in employing the application and the associated risks, developers might opt to test its operation in a specific firm area with just one or two individuals.

Occasionally, they run both the old and new systems in parallel to compare results. In alternative scenarios, developers cease using the old system one day and initiate the use of the new system the next. To execute data assimilation for the proposed LWSN, we apply Algorithm 1[15], an extended Kalman filtering algorithm, to the data collected from the LWSN and the concentrations of air pollutants. Notably, if the fractional-order derivative is substituted with a conventional derivative, the algorithm becomes the extended Kalman filter (EKF).

In terms of software packages for fractional-order systems, various fractional-order model (FOM) identification toolboxes exist, such as CRONE toolbox and FOMCON toolbox. They rely on Hartley and Levy algorithms for obtaining a commensurate fractional-order transfer function (FOT). The FOMCON toolbox comprises modules for fractional-order analysis, identification (time and frequency), control (fractional-order proportional-integral-derivative (FOPID)), and implementation (digital and analog fractional order (FO)) [6]. Leveraging these advantages, we utilized the FOMCON toolbox for identifying fractional orders in the time domain. Implementation, in essence, is the process of transforming a new or revised system design into an operational one. User education ideally should have occurred earlier in the project during the investigation and design phases. Training users on the new system is imperative. Following user training, the system undergoes hardware and software security testing to ensure successful future implementation.

The system's implementation toward structuring forecast models primarily involves three stages:

1. **Data Pre-processing:** The initial step in building a forecasting model is data pre-processing, involving data cleaning, filling missing values, removing anomalies, and organizing data to suit Machine Learning algorithms.
2. **Feature Engineering:** Features play a crucial role in enhancing prediction accuracy, such as day, month, time of day, etc.
3. **Building Forecasting Model:** The model is constructed to predict the future based on subtle data derived from historical information.

VII. RESULTS AND DISCUSSION

. The processor selected for the system is the Arduino, functioning as the motherboard. Connected to the processor are temperature sensors, smoke sensors, and radiation sensors. If the smoke sensor detects smoke surpassing 613, it notifies the processor[15]. Subsequently, the processor sends a GSM message immediately, including the recorded temperature at that moment. Similarly, if the radiation sensor detects radiation beyond the range of 250, the same process is triggered. When pollution exceeds the predefined threshold, a GSM message is dispatched to the authorized person. Upon receiving this message from GSM, the power supply to the industry can be remotely severed via IoT. The IoT-based pollution monitoring and control system, utilizing the Arduino motherboard, is devised to detect smoke, temperature, and radiation. If any pollution is identified, the power supply to the respective industry is disconnected, preventing further pollution emissions. This robust system proves highly beneficial for industries grappling with escalating pollution issues. The project's outcomes are precise, making it applicable across various industries to safeguard workers and the environment[13]. Every industry, irrespective of scale, is encouraged to adopt this system for emissions monitoring. The system incorporates sensors that identify pollution-causing parameters. Whenever these parameters exceed defined levels, the sensors relay a message to the authorized personnel through GSM. The authority, with the assistance of IoT, can then deactivate the power supply to the polluting industry. The system operates wirelessly using IoT principles.

VIII. CONCLUSION

Wireless sensor networks find applications in various fields, playing roles in environment monitoring, habitat observation, and healthcare. These networks demonstrate resilience in harsh environmental conditions, offering ease of use and management. Unattended operation and adaptability to node failures are additional features. The Zig Bee protocol, based on 802.15.4, is specifically crafted for short-range, low-data-rate wireless sensor networks (WSN). The inaugural operating system tailored for WSN was TinyOS, grounded in an event-driven programming model as opposed to multithreading. To address power consumption constraints in WSN, data aggregation proves useful.

Leveraging WSN for environmental monitoring and pollution control offers advantages, with sensor nodes being lightweight, easily installable, low-power, and cost-effective. These nodes, with limited energy storage, eliminate cable hassles and offer mobility. Consequently, the flexibility, fault tolerance, high sensing fidelity, low power consumption, low cost, and rapid deployment features of wireless sensor networks open up novel application areas for remote sensing. Despite these merits, WSN does have drawbacks, including limited communication speed, reduced security, complex configuration, susceptibility to external factors like microwave ovens, interference from elements like Bluetooth, and challenges in sensing quantities within buildings. However, future advancements may facilitate easier data gathering, minimize inaccuracies, save power consumption, and contribute to pollution reduction in affected areas.

Sensor networks, given their extensive applications, are poised to become integral aspects of our daily lives. A critical constraint for sensor nodes is their low battery power, often irreplaceable. While realizing sensor networks, it is essential to address constraints related to fault tolerance[15], reliability, scalability, cost, hardware, and topology changes. Despite these challenges, wireless sensor networking holds a promising future in computer networking, offering advanced solutions to monitoring problems in the times ahead.

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