Survey on Air Quality Monitoring System Using Wireless Sensor Network

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Abstract:

This paper presents a survey on Air Quality Monitoring. Air pollution worldwide is a growing threat to human health and the natural environment. In our daily life we come across many airborne chemicals. An estimation of 4.6 million people die each year from causes directly attributable to air pollution (50% deaths occur in India and China alone). In order to protect the world from being polluted and save life, it is necessary to measure the quality of air. The air quality is determined by measuring the major air pollutants such as levels of particle pollution (particulate matter (PM)), ground-level ozone (O_3), carbon monoxide (CO), sulphur oxides (SO), nitrogen oxides (NO). The pollutant levels measured by various sensors are transmitted to the base station using a Wireless Sensor Network (WSN). The output is displayed to the user.

Keywords — **Air quality monitoring, Wireless Sensor Network (WSN), ZigBee, Arduino, Internet of Things (IoT).**

I. INTRODUCTION

In recent years, more than 80% people are exposed to air pollution. The survey says that it exceeds the World Health Organization (WHO) limits. As the population increases with the evolving technologies, the pollution also increases. The decrease in air quality creates a great impact in health of the people. The tiniest particles that are about 30 times smaller than the width of hair which comes from vehicles, factories, biomass combustion and construction dust, among other sources can penetrate deep into our lungs, leading to a large number of heart and lung diseases. Kanpur is the most polluted city in India and the next is Delhi. They say that there are no protocols or guidelines to control the air pollution in Kanpur. The main reason is due to the presence of large amount of small scale industries. The polluted air when inhaled can cause loss of lung capacity, decreased lung function, development of diseases such as asthma, bronchitis, emphysema, and possibly cancer. In order to evaluate the effectiveness of emissions control strategies, provide information on air quality trends; provide data for the evaluation of air quality models, the quality of air should be monitored.

II. RELATED WORK

"A Wireless Sensor Network Air Pollution Monitoring System (WAPMS)" proposed by Kavi K. Khedo monitors air pollution through the use of wireless sensors. It was proposed in 2010[1]. The aim of this paper is to monitor the high risk regions. WAPMS makes use of an Air Quality Index (AQI) to measure the values of various gases. In order to improve the efficiency of WAPMS, they have designed and implemented a new data aggregation algorithm named Recursive Converging Quartiles (RCQ). RCQ is used to merge data to eliminate duplicates, filter out invalid readings and summarize them into a simpler form. Thus it significantly reduces the amount of data to be transmitted to the sink which saves energy. This is the advantage of this paper. RCQ has two operations:

- Duplicate Elimination Technique
- Data Fusion

The sensor nodes collect data autonomously and transmit to the database via wireless network. The collected readings are saved in a database and these can be accessed individually in a table or summarized area wise in a line graph. The table uses the AQI to provide the results using the associated colors and it also provided the level of health concern for a particular area. The line graph allows the user to view the trend of air pollution for several areas at a time.

Srinivas Devarakonda presented "**Real-time Air Quality Monitoring Through Mobile Sensing in Metropolitan Areas**" in the year 2013[2] in which he proposed a vehicular-based mobile platform which can be used for measuring fine-grained air quality in real-time. This model uses two data farming models which can be used for

- Public Transportation Sensing
- Personal Sensing

Both the models have many challenges which also provide redundancy. For the public transportation purpose, a mobile sensing box integrated with Arduino microcontroller, cellular modem and GPS is used. The second model uses a NODE Wireless Sensor platform to connect to the smart phones. They used Google Fusion Tables as the cloud storage service whose cloud server is deployed on EC2 with classic LAMP settings. Both the models concentrate mainly on sensing the poisonous carbon monoxide (CO) gas.

The paper "**Indoor Air Quality Monitoring System using Wireless Sensor Network (WSN) with Web Interface**" presented by Shaharil Mad Saad in 2013[3] propose a system to measure the IAQ parameter in real time. They focus mainly on the temperature and humidity in the air to determine the indoor quality. The sensing module used in the system consists of a WSN node which is connected through wire-based connection. The IRIS Wireless Sensor Network node which is low cost is used for the transmission of data. TinyOS is used to program this mote which is also used to implement wireless mesh communication network. The system is mainly used to measure the volume of heat, ventilation etc in buildings.

"Wireless Sensor Network for Real-Time Air Pollution Monitoring" in 2013[4] presented by Abdullah Kadri proposes an ambient real-time air quality monitoring system. The system provides machine-to-machine communication. The system has two main components.

- Multi-gas (MG) monitoring stations
- M2M platform

The MG monitoring station consists of various gaseous sensing elements which are based on nanotechnology semiconductor concept. Atmega 2560 microprocessor is used for wireless communication. At the backend M2M platform is used which contains different modules such as M2M communication module, data integrity module, data processing module, data storage, and prediction module. The M2M communication protocol connects all the MG monitoring stations. The monitoring stations communicate in an M2M fashion with a backend server using GPRS communications.

The system generates an alert message in the form of SMS when pollution level exceeds a certain value.

Samer Mansour stated "**Wireless Sensor Network-based Air Quality Monitoring System**" in 2014[5]. In this paper he introduced two things:

- Libelium's Wasp mote
- Clustering Protocol of Air Sensor network(CPAS)

In the implementation part, the waspmotes generate the sensor values. They form a low power ZigBee-based wireless mesh network. The Wi-Fi module transmits the data to the database which is also sent to the web servers. The alert mail/message will be sent to the appropriate user when the sensor values exceeds than the threshold values.

In the proposed CPAS protocol, we find the direct transmission of data from both the active nodes of a cluster and CH to the base station which involves low energy consumption.

Farid Touati presented **"Feasibility of Air Quality Monitoring Systems Based on Environmental Energy Harvesting"** in 2015[6]. He proposed a multiparametric smart SENNO (SENsor Node) to monitor the quality of air. The device measures various gases such as barometric pressure and temperature, hydrogen sulphide, nitrogen dioxide, carbon monoxide, chlorine and ammonia.

The harvesting technique is adopted in which scavenging energy is considered in order to increase the battery storage capacity. The integrated LTC3109 together with the LTC3330 converters ideal for harvesting surplus energy from extremely low input voltage sources.

A tailored calibration process is used to trace the air quality levels in indoor and outdoor application, in a sort of "set and forget" scenario. The advantage of the system proposed in this paper is that it can work without battery and human intervention, harvesting energy from the surrounding environment for perpetual operation. This system uses a renewable energy-harvested sensor system SENNO that intelligently manages continuous energy transfer without human intervention during air quality monitoring.

"Air Pollution Monitoring System using LabVIEW" is presented by Souhir BEDOUI in 2015[7]. The system designed in this paper measures the levels of hydrogen sulphide gas (H2S), temperature and humidity. The air quality is measured in real-time using the ZigBee wireless sensor network.

The major advantage of this paper is the use LabVIEW software which acts as a graphical user interface (GUI) and so it is fast and simple. It uses a dataflow programming data to determine performance. The design also utilizes low power and low cost.

Chen Xiaojun stated in the year 2015[8], "**IOT-Based Air Pollution Monitoring and Forecasting System"**. This paper presents a real-time air pollution monitoring and forecasting system based on Internet of Things (IOT). An Air Quality Index (AQI) is used to analyze the input values. The system exhibits the function of forecasting development. It comprises of three layers:

- Perception Layer
- Network Layer
- Application Layer

The perception layer is based on front-end acquisition device. The network layer is for environmental and meteorological data transmission. The application layer performs data analysis, evaluation and data prediction. Air pollution prediction is a multiple-input-multiple-output forecasting tool based on neural network technology which has high extensibility. It ensures monitoring accuracy reduces monitoring cost and makes monitoring data in monitoring area more systematic and perfect since large number of sensors involved. A large number of field data provided by front-end sensor network makes big data analysis in background application layer more direct and effective, providing a real and effective decision-making basis for emergency response. Yeelink is used for IoT in which the collected data is displayed.

The advantage of this system is that it can reduce the hardware cost into 1/10 ensures monitoring accuracy and makes more systematic and perfect.

"A Low-power Real-time Air Quality Monitoring System Using LPWAN based on LoRa" presented in the year 2016[9] by Mr. Sujuan Liu, used LoRa wireless communication technology. It provides a low cost solution for monitoring the quality of air. It has several advantages such as easy to operate, long distance, high coverage, efficient self-supply, long device battery life, and high capacity, fast response time with accuracy. The self-sustainable energy supply is provided by a solar PV-battery.

This paper is an IOT-based real-time air quality monitoring which uses LoRa technology. Sensing module consists of LPWAN node connected through wireless connection. Data from microcontroller is being sent to LPWAN nodes using LoRa modem. Finally, the computer receives data from the nodes which permits end users to obtain the data of the monitored areas over a long period of time.

Dongyun Wang in the paper "**Design Of air quality monitoring system based on Internet of Things**" presents an Ethernet remote monitoring and control system which was presented in the year 2016[10]. This system can be used to measure the temperature, humidity and particulate matter. It is a ZigBee and web system based system. It is divided into two main parts, namely,

- Gateway
- Sub-node

The system is based on LM3S8962 chip which is the heart of the gateway. The gateway is used for network transmission and real-time display. The sub nodes are for acquisition of sensor data. The communication protocol has some formats like frame header, checksum, short address, SPK control, LED control, LED flag and end of frame. The common network data centre networking platform-yeelink is used which provides access, storage and data display. The stability and ultra-low power consumption are the major advantages of this system.

"Design of Outdoor Air Quality Monitoring System Based on ZigBee Wireless Sensor Network" by Yun-Liang Hel et al in 2016[11] presents ZigBee based real time air quality monitoring system. They make use of CC2530 chip, consists of ZigBee protocol called Zstack, to build ZigBee network quickly. OSAL (Operating System Abstraction Layer) is a real-time operating system in Zstack.

ZigBee wireless sensor network is used for data transmission. The main focus of this system is to measure the outdoor gases like Sulphur dioxide (SO2), Nitrogen dioxide (NO2), Ozone (O3), Nitrogen oxide (NO) and Carbon monoxide (CO).

The major advantages of this system are low cost, less complexity and cost of wiring, enlarged range of monitor and improved mobility.

The proposed system plays a significant role in national security, economic development, military, industry, agriculture, transportation, medical, home office automation and other fields.

"Air Pollution Monitoring Using Wireless Sensor Network" by Bhavika Bathiya in the year 2016[12] proposed low cost multi-sensor node to measure the air quality. The system uses a multi-hop wireless sensor network algorithm to aggregate the sensor data from different nodes. The data transmission is made through Arduino UNO microcontroller. They use MOS sensor to detect low ppm concentration. XBee series 2 based on ZigBee protocol is used as a RF module in this proposed system. Tree based protocol is used to transfer data to sink.

The device has some limitations such as absence of sleep mode in router, delay in network joining, high current consumption and chance for false data of temperature and humidity values.

"Optimization of Air Quality Monitoring Network Using GIS Based Interpolation Techniques" proposed by Mohammed Mujtaba Shareef in 2016[13] presents a simple method of optimizing Air Quality Monitoring Network (AQMN) using Geographical Information System (GIS), interpolation techniques and historical data. Existing air quality stations are eliminated and the missing data are filled in using the most appropriate interpolation technique. The interpolated data are then compared with the observed data. Pre-defined performance measures root mean square error (RMSE), mean absolute percentage error (MAPE) and correlation coefficient (r) were used to check the accuracy of the interpolated data. An algorithm was developed in GIS environment and the process was simulated for several sets of measurements.

Petr Brynda in **"Mobile Sensor Unit for Online Air Quality Monitoring"** presented in 2016[14] states that the proposed system make use of sensor units for monitoring the pollution of air in urban areas. The system uses low energy communication module, Bluetooth and measures the level of Carbon Monoxide, Sulphur Dioxide, Nitrogen Dioxide, Volatile Organic Compounds and photoionization detector. The used microcontroller consists of Bluetooth Low Energy (BLE) communication interface. Mobile phone uses Bluetooth Low Energy GATT (Generic Attribute Profile) transactions for two way data transfer. It also includes GPS position and time of measurement. The data connectivity in the smart phone is used to send the data to a server. The server stores the data in environmental database and provides API interface. Mobile sensor units provide small, low cost means of air quality tracking. The system focuses on pedestrians, joggers and cyclists to use the application. The additional function provided by this system is that the users can send queries by taking photo and commenting on it.

In **"Design and Implementation of LPWA-Based Air Quality Monitoring System",** Kan

Zheng proposed a system based on IoT in 2016[15]. It makes use of portable sensors to measure the air quality. On the software side, the system is adapted to a three-tier hierarchical IoT architecture.

- Sensing Layer
- Network Layer
- Application Layer

On the hardware part, it includes

- Monitoring Node
- Access Point (AP) Node

The system contains different modules such as power module, controller module, LPWA Transmitter module, sensor module. These modules come under the monitoring node. The services to be provided to the user are done using HTTP protocol. The system covers a large area to monitor using LPWA network.

"Urban Air Pollution Monitoring System with Forecasting Models" presented by Khaled Bashir Shaban in 2016[16] proposed a low-cost air-quality monitoring system. The system consists of multi-gas sensing (MGS) devices and an intelligent sensing and services machine-to-machine (M2M) platform.

The MGS device includes gaseous and meteorological sensors which are exposed to ambient air every 15 minutes. These nodes wirelessly communicate to an intelligent sensing platform that consists of several modules namely,

- M2M communication protocol
- Data integrity
- Data processing
- Prediction and analysis
- Database management

These modules are responsible for receiving and storing the data, preprocessing and connecting multi-gas devices. This paper mainly focuses on the forecasting module. The system undergoes investigation of three machine learning (ML) algorithms to build accurate forecasting models. Two types of modeling are pursued:

- Univariate
- Multivariate

The multivariate modeling approach is used to enhance the prediction accuracy and reduce error. As a result the best root mean square of various gases is achieved.

Navreetinder Kaur presented **"Air Quality Monitoring System based on Arduino Microcontroller"** in 2016[17]. He proposed Wireless sensor network (WSN) based framework for transmission of data. In the implementation part, the input from various sensors is transmitted to Arduino UNO microcontroller. These values are transmitted to three different modules namely, ZigBee, GSM module and Bluetooth module. The user can view the results received at the base station via ZigBee module. A warning is triggered in the form of message when the poisonous gas carbon monoxide gas exceeds the threshold level. As the buzzer is set, necessary precautions can be made before any accident.

T Appa Rao in the imperial journal 2017[18], **"IoT Based Air Pollution Monitoring System"** designed a system that measures the level of various gases like Carbon dioxide (CO2), smoke, alcohol, benzene and ammonia. The system uses MQ135 gas sensor to monitor air quality. It also contains Arduino microcontroller, ESP8266 Wi-Fi Module.

In the implementation side, the input from the sensor is transmitted to the LCD screen through the Arduino microcontroller and Wi-Fi module. An alarm will be triggered whenever the air quality exceeds the threshold level. The output is displayed in the LCD screen.

"IOT Based Air Pollution Monitoring System" by K.Nirosha in 2017[19] proposed the system that will monitor the Air Quality over a web server using internet. MQ135 sensor is used to detect the most harmful gases more accurately. The gases being measured by this system are ammonia, alcohol, smoke, carbon dioxide, benzene. The system uses Arduino UNO microcontroller and ESP866 standalone Wi-Fi module. FTDI is used to connect to the computer. Pollution level can be monitored from anywhere using computer or mobile. An alarm is triggered when the input value exceeds the threshold value.

The advantages of this system are portable and flexible device, reduced error, cost effective and easy construction.

M.F.M Firdhous presented **"IoT Enabled Proactive Indoor Air Quality Monitoring System for Sustainable Health Management"** in the year

2017[20]. The main aim of this paper is to keep track of the ozone concentrations near photocopy machines. Thus it is a single gas sensing device.

The system consists of Arduino BT board, ozone sensor, a gateway node and a processing node. The sensing node is built using Arduino BT board and Raspberry Pi-3 is for gateway node. They use an IoT device for the data collection. A warning will be generated by the system whenever the pollution level increases beyond certain value.

III. WORKING PRINCIPLE

The working of air quality monitoring system starts from the sensor node. The sensor sense the appropriate gas and transmit it to the microcontroller device, maybe Arduino or Raspberry pi or other which converts the analogy data into digital form. The input data has to be viewed by the user for future analysis. For this the digital data is sent through a wireless communication technology, namely ZigBee gateway, Bluetooth or Wi-Fi module. It is received at the base station. The input data is stored at the database where it is aggregated. The stored data is sent to the IoT cloud platform where the data can be viewed from anywhere. The overall architecture of the system is:

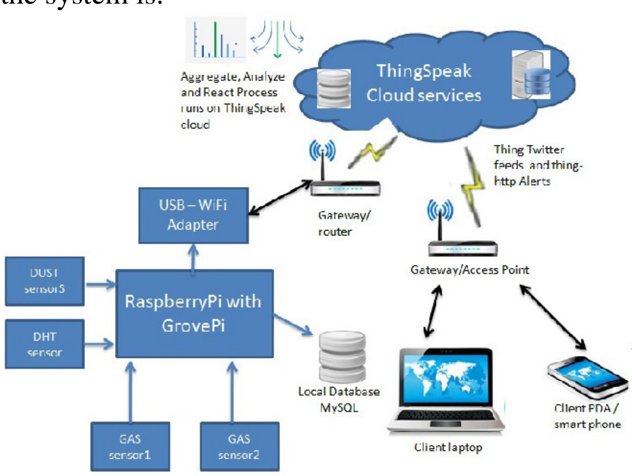

Fig 3.1: Overall system architecture

IV. COMPARATIVE STUDY

The major air pollutants are ozone, particulate matter, nitrogen dioxide, carbon monoxide and lead. Their sources and impact on human health are as follows:

Pollutant	Source types and major sources	Health effects
Particulate matter	Primary and Secondary-Burning of fossil fuel, wood burning, dust storms, forest fires	Respiratory symptoms, decline in lung function, asthma, mortality
Ozone	Secondary- Formed through chemical reactions of anthropogenic precursors in the presence of sunlight	Decreased lung function, eye irritation
Nitrogen dioxide	Primary and Secondary-fossil fuel combustion, kerosene heaters, lightning	Decreased lung function, increased respiratory infection, acid precipitation
Sulphur dioxide	Primary- fossil fuel combustion, household coal use, oil refineries	Lung impairment, respiratory symptoms, acid precipitation

Table 4.1: Major pollutants, sources and their effects

Nowadays, many different technologies for gas detection are available, each with certain advantages and disadvantages. To date, there are five types most suitable and widely used low-cost portable gas sensors, namely electrochemical sensors, catalytic sensors, solid-state (semiconductor) sensors, non-dispersive infrared radiation absorption (NDIR) and photo-ionization detector (PID) sensors.

Sensor Type	Detectable Gases	Power Consumption	Response Time	Life Expectancy
Electro-chemical	Gases which are electrochemically active, about 20 gases	Lowest, very little power consumption	<50s	1–2 years
Catalytic	Combustible gases	Large, need to heat up to 400 ◦C to 600 ◦C	<15s	Up to 3 years
Solid-state	About 150 different gases	Large, need heating element to regulate temperature	20s to 90s	10+ years
Non-dispersive Infrared	Hydrocarbon gases and carbon dioxide	Small, mainly consume by the infrared source	<20s	3–5 years

Photo-ionization	Volatile organic compound (VOCs)	Medium, mainly consume by the ultraviolet source	<3s	Depend on the Ultraviolet lamp, normally 6000 h

Table 4.2: Comparison of different types of gas sensors

V. CONCLUSION

This paper presented a survey on real-time air quality monitoring. The system utilizes various wireless sensor networks. The sensor data provides the composition of each gas, their levels, the area and the time of measurement. The output analysis can be viewed in computer or the mobile phone and the precautionary steps can be made effectively based on it.

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