IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)
An International Open Access, Peer-reviewed, Refereed Journal

Air Quality Monitoring Systems: An Analysis of Existent Air Quality Monitoring and Management Systems

Aditya Khandelwal[1] Shrikant Bhange[2] Suraj Badgujar[3]Chetan Pawar[4]

[123]Student, [4] Assistant Professor
[1]Electronics and Telecommunications Department,
[1] Pune Institute of Computer Technology, Pune, India.

Abstract: *T*he rise in global emission and degradation of air quality due to carbon compounds, sulphates, particulate matter, etc. across the globe as a result of industrial processes and the use of fossil fuels, among others, pose the foremost challenge of modern society, with the recent CO_2 emission level being as high as 37.12 billion tons in 2021 as opposed to 34.49 billion tons in 2011, a rise of over 7% within a decade [1]. Industrialization and modernization require a continuous need for energy, and industrial activities generate huge amounts of pollution. Just as industrialization is essential for societal development, controlling the emission levels is essential, as the effects of air pollution are not limited to global warming, mass extinction of species, derogatory impacts on human health, and economic setbacks. It has become the need of the hour to monitor the same in order to create an action plan against this aggravating problem. This paper explores the development various air quality monitoring systems through various technologies and the future scope in the same.

Index Terms - **Global Emission, Air-Quality monitoring systems, IoT, Blockchain.**

I. INTRODUCTION

The rapid degradation of air quality has been the prime concern of innumerable environmental activists, academics, and the general populace alike. According to reports by the World Health Organisation (WHO), a full 99% of the global population breathes air containing too many pollutants [2], and more than seven million people are killed because of exposure to pollution [3]. The extreme threat posed by the rapid degradation of air quality calls for efforts to track, manage, and reduce the pollution. Traditional air-quality monitoring systems are based on chemical analyzers, but they are expensive and bulky, and for this reason, they do not have a high spatial resolution. Since the 1990s, the development of various sensors for the detection of particulate matter in air and carbon and sulphate-based gases has brought about the evolution of air quality monitoring systems. The further optimisation of the said sensors and systems led to the evolution of IoT-based models that can perform monitoring more accurately and efficiently with higher space-time resolution, which has also enabled the analysis of historical time series data of pollutant concentrations, allowing the development of

air-quality forecasting models. Within the scope of this paper, we explore various models since the advent of such monitoring systems and discuss the various potential improvisations in the same.

II. REVIEW OF KEY DEVELOPMENTS IN AIR-QUALITY MEASURING SYSTEMS:

2.1Air Quality Monitoring System based on the Internet of Things (IoT)

This study aims to design and deploy an air quality monitoring system for the city of Tasikmalaya, Indonesia, based on the Internet of Things (IoT). The sensors used are MQ-131, MQ-7, and MQ-4 for ozone, methane, and carbon monoxide, respectively, along with Arduino microprocessors. The sensor data is sent to the internet and visualised in graphs on the web in real time through various analytics software [8]. The model is enclosed in an encasement wherein all the IoT modules have been encased, the calibration of the sensors is performed manually and matches the references, and the testing is done by using the sensor data in the field and the stability of sending data on the internet.

The results of this IoT model are based upon the analysis of the data collected by the device and plotted on various graphs. This is an instance of a well-developed and deployed IoT-based air-quality monitoring system. Some of the results generated by the same are as follows:

Date	Carbon monoxide (CO)	Methane (CH_4)	Ozone (O_3)
17 September 2019	0.80 ppm	348.32 ppm	0.04 ppm
18 September 2019	0.90 ppm	348.95 ppm	0.08 ppm
19 September 2019	1.68 ppm	345.88 ppm	0.03 ppm
20 September 2019	1.19 ppm	336.80 ppm	0.04 ppm
21 September 2019	1.30 ppm	339.20 ppm	0.04 ppm
22 September 2019	1.56 ppm	308.63 ppm	0.07 ppm
23 September 2019	1.93 ppm	317.16 ppm	0.06 ppm
24 September 2019	2.35 ppm	315.68 ppm	0.06 ppm
25 September 2019	2.43 ppm	310.33 ppm	0.03 ppm
26 September 2019	0.93 ppm	328.54 ppm	0.48 ppm
Average	**1.51 ppm**	**329.95 ppm**	**0.09 ppm**

Table i: Results of air quality in the city of Tasikmalaya [9]

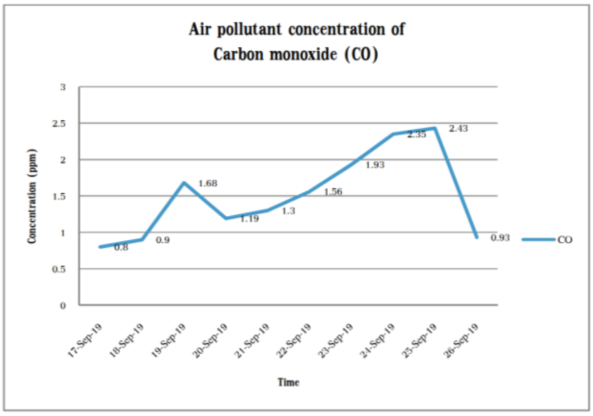

Fig. i: Result of the analytics developed through the reading of the deployed model [10]

2.2IoT Enabled Air Quality Monitoring System Using LoRa and LPWAN

Traditional air quality monitoring systems employ air quality measuring sensors, a Zigbee module, a suitable 16-bit microcontroller, a GPS module, and a GSM module. The use of the GSM module enables tracking of the location from which the data is being generated, i.e., remote monitoring of air quality. This traditional system poses some drawbacks, like increased power consumption by the ZigBee module, limited processing capacity of a 16-bit microcontroller, and increased implementation costs for incorporating a GSM and GPS module [4]. Within the scope of this study, an IoT-based monitoring system has been developed to measure, monitor, and gather the data of air quality from multiple nodes and display it in a single database. The proposed model employs LoRa LPWAN (Low-Power WAN) gateways, the major advantages of which are the low power consumption, easy gathering of data from multiple nodes, high processing speed, reduced cost, and low latency time. After getting all the parameter values to display locally, you can upload them to any IoT cloud platform. Here, this research work has proposed the Ubidots IoT Platform.

The model includes an Arduino Nano as its microcontroller, a DHT22 temperature and humidity sensor, an MQ-7 sensor module to measure CO (Carbon Monoxide), an MQ-135 universal sensor that measures almost six different gases, including NH3, BEH, Butane, LPG, and finally CO2 [5], a dust sensor, an LCD display module for local display of air quality, and an Ubidots IoT platform to send data to the cloud and generate different real-time analytics mediums like graphs in real-time. This module is a low-power, long-range wireless communication module that is designed as an efficient communication platform for low-powered devices and works at 868 MHz.

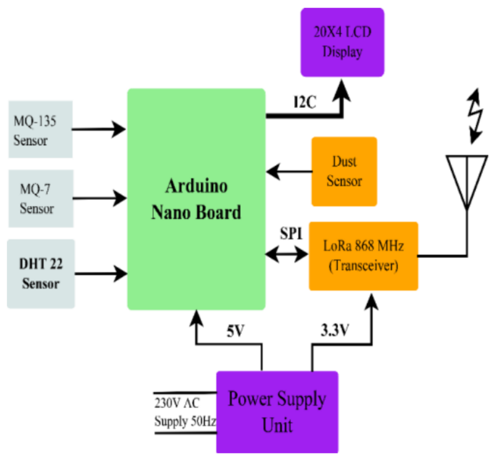

Fig. ii: Structure of LoRa 1278 Transceiver [6]

The model under discussion in this paper overcomes the typical system's constraints, which are related to the disadvantages resulting from loss of internet connection, more latency time, higher power consumption, etc. The proposed system is smaller in size, more affordable, more accurate, lighter, and operationally less complex. The outcomes are precise, with low power consumption and increased efficiency. The analytics of all the end device data map a suitable widget in Ubidot's IoT Cloud platform to visualise the data for user-friendliness. The main advantage of these LoRa nodes is that we do not need Internet for all the nodes except the gateway (server) to monitor all parameters with analytics. LoRa protocol, especially its very low power consumption, is ready to use, and the security level is more robust and secure with AES-128 [7]. Thus, this is an upgrade over the traditional IoT-based monitoring systems.

2.3PCA scheme for sensor FDI: Application to an air quality monitoring network

The previous models established an IoT system that measured quantitatively the quality of air in the region where it was deployed, along with optimisation in the same model using LoRa. This study explores a sensor fault detection and isolation procedure based on principal component analysis (PCA) that is proposed to monitor an air quality monitoring network. The PCA model of the network is optimal with respect to a reconstruction error criterion [11]. This is essential for the effective calibration and operation of the monitoring system. The sensor fault detection is carried out in various residual subspaces using a new detection index. This sensor validation is performed on an AIRLOR, an air-quality monitoring system deployed in France that is used to measure the concentrations of various pollutant gases. The methodology of the same is outside the scope of this paper; we will explore the principle, i.e., PCA fault detection and isolation, superficially and study the outcomes of the same.

PCA Modelling

Principle Component Analysis is one of the most popular statistical methods for extracting information from measured data and finds the directions of significant variability in the data by forming linear combinations of variables [12]. After the presence of a fault has been detected, fault isolation takes the necessary corrective actions to eliminate the abnormal data. This entire procedure would make the data thus extracted and the system much more reliable and fault-tolerant.

The setting for the deployment of the foregoing system is Lorraine, France, and consists of more than twenty stations placed in urban, peri-urban, and rural regions. Each station can be considered an IoT model that measures the concentration of various pollutants in the air and creates a database of the same. The measures of the following system are averages calculated over fifteen minutes in order to limit the spatial and temporal sampling problems.

Results**:** This study established a method for creating a fault-tolerant air-quality measuring network using the PCA FDI scheme. Considering the high degree of redundancy among the process variables, this procedure is based on the variable reconstruction approach in order to design the PCA model of the network, isolate the faulty sensors, and estimate the fault amplitudes. Some analytical results obtained during the study are as follows:

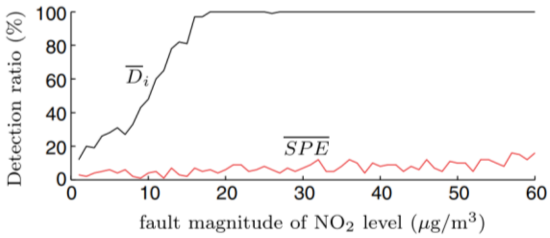

Fig. iii: Fault levels detected in NO_2 Levels [13]

2.4Novel Air Pollution Measurement System Based on Ethereum Blockchain

The air quality systems we have explored till now have undergone various stages of development, from the measuring models to making the system reliable and the data easier for analysis using various specific types of sensors and statistical analysis techniques. Now, we explore a use case that employs blockchain technology under the thus-developed IoT network to introduce characteristics of decentralised organisations, eliminating points of vantage all the while increasing the transparency and traceability of the system.

The pollution monitoring and reporting systems have been found compromised time and time again, with such devices being altered to give false readings. The misreporting of information [14] [15], the tampering of published data, and the fines imposed by the pollution control boards are some prevalent issues that need to be solved to improve the overall situation of air-quality monitoring and management. One such method that can be employed to tackle all the aforementioned problems is the use of blockchain technology along with a monitoring system; this will counter such issues.

This study employs the Ethereum blockchain architecture for the data generated by an IoT sensor network to monitor the pollution and tackle the prevalent challenges of such monitoring systems using the inherent characteristics of blockchain. The data used in this study is generated from a real-time on-road monitoring station network operating in Milan [16], which is stored in the Interplanetary File System (IPFS), a protocol, hypermedia, and file-sharing peer-to-peer network for storing and sharing data in a distributed file system. IPFS has been implemented to create a hash for the air-quality data that has been stored in a decentralised network using the same; this hash would thus reduce the cost per transaction to nearly one hundredth of a euro.

Transactions between two digital wallets that enable users to store and manage their Bitcoins and Ether are the foundation of blockchains. The idea is to transfer transactions between the two wallets belonging to the same owner that include the relevant data in order to change the true purpose of the latter and transform them into genuine registers where each transaction serves as the tool for data validation [17]. The information collected from the transactions in this wallet is legitimate and unchangeable since the wallet receiver has the validating registers and the verified transactions are delivered to it.

The system creates a user-friendly blockchain solution for storing data. However, by using a few straightforward options from the command line, it is possible to send a transaction and find the information from the latter in such a way that the data used are the validated ones. There are no issues with interacting with external software to create and send data through transactions.

The air quality monitoring sensor uses an LTE connection to transmit the measured data to the server.

According to blockchain policies, the actual string must be converted into hexadecimals before being sent as part of the transaction. Before displaying the results in crystal-clear detail, sending a string of this type has a high cost per transaction, which is not ideal for cost optimisation [16].

This made it possible to store, on the Ethereum blockchain, the data on the average concentration of zones referred to as the main areas of Milan. The return data refer to the average concentrations of NO2, O3, PM1, PM10, PM2.5, pressure, temperature, traffic, humidity, and VOC. Time traceability was guaranteed by considering the time stamps as fixed dates on the blockchain concerning the data sampling dates. This tool has allowed the data amount to be reduced and subsequently the transaction cost, optimising the economic aspect of this tool. After writing the data in the blockchain through the transaction, recovery, and management systems, it was possible to process and present information regarding the measured parameters by accessing the hash of a certain block and further using the IPFS file hash to retrieve the data stored in the same.

III. DISCUSSION

The various developments and improvisations of the air-quality monitoring and measuring systems have started from simple IoT devices displaying the air-quality locally to a network deployed on an underlying blockchain that automates the data publishing over the WEB removing agents like cloud providers, all the while introducing the properties of immutability, traceability, and transparency to the data generated.

Further explorations in such monitoring systems can be made in the following manner:

1. The blockchain network can be used to create a decentralised managerial body similar to pollution control boards using smart contracts. This smart contract would operate based upon a set of predetermined rules limiting the values of emissions. The industrial emissions can easily be segmented and targeted by such a model, which monitors the concentrations of emissions and automates the process of issuing fines against specific industrial polluters that release high concentrations of pollutants in their vicinity. The smart-contract would also take corrective actions against the same industries if their emissions are higher than the permitted value, thus removing the middlemen like pollution control boards and making the entire system transparent and virtually impenetrable.
2. Optimisations in the sensors and IoT network used, including the protocol stack of the network, to ensure autocalibration of the same in accordance with current atmospheric conditions in the region of their deployment to gain standardised results for analysis between different regions This also includes

adopting low-power devices along with a backup power and internet source to keep the network up and running in times of electricity or internet cuts.

3. Recent innovations in Artificial Intelligence, Machine Learning and Industry 4.0 can lead to industrial optimisation wherein the system would moderate industrial activities and control the emissions and pollution outputs of the industrial processes by altering the process frequency to give out an optimised output factoring in various parameters like emissions generated, demand of the industrial product being generated, weather conditions, economic factors etc.
4. Global leaders in computing and technologies are undertaking various efforts towards the development of technologies for a sustainable future, and the output of such efforts will bear fruit for human society in general. This includes IBM's Green Horizons Initiative to address the challenge of accurate forecasting of air quality using Artificial Intelligence and the Internet of Things (IoT), the United States Department of Energy's SunShot initiative to make renewable energy forecasting technologies available to various agencies, amongst others [19]. Such initiatives would have a great cumulative impact on the management of the existential crises related to pollution.

The way this exploration would occur is diverse, with different innovations breeding in different regions across the globe, but the end impact is the same: tackling the problems of the modern era, including pollution, using technology.

IV. Acknowledgment

The application of knowledge gained through academic years is nourished when practical implementation takes place. During the execution of this project, we have implemented various theories and implemented principles studied in theory over the course of our education along with exploring various new-technologies, latest innovations in relation to our study topic. We are filled with gratitude for the opportunity to implement the same for this opportunity to publish our survey paper titled, "**Air quality monitoring systems: A review of existent air quality monitoring and management systems**" which is a part of our Be-Project. We would like to express our heartfelt gratitude towards **Dr. S. T. Gandhe**, Principal PICT and **Dr M. V. Munot** Head of Department (**Electronics and Telecommunication**), for providing us with all the necessary resources for the successful research and implementation of our project. It would have been an impossible task without the guidance of our guide **Mr. Chetan C. Pawar** and his constant motivation for the same for which we are filled with gratitude. We would also like to express our gratitude for all the lab asst and dept staff for their continuous guidance. At last, we are acknowledging all the authors of the references and other literatures referred in this project.

REFERENCES

[1] CO2 emissions - Our World in Data

[2] 99 percent of humans breathing polluted air, situation worst in poor nations (rfi.fr)

[3] WHO: 99% of World Population Breathes in Polluted Air (voanews.com)

[4] [5] [6] Kuncoro, Aditiyo & Mellyanawaty, Melly & Sambas, Aceng & Maulana, Dian & Subiyanto, Subiyanto & Mamat, Mustafa. (2020). Air Quality Monitoring System in the City of Tasikmalaya based on the Internet of Things (IoT). Journal of Advanced Research in Dynamical and Control Systems. 12. 2473-2479. 10.5373/JARDCS/V12I2/S20201294.

[7][8][10] Raghuveera, E. et al. "An IoT Enabled Air Quality Monitoring System Using LoRa and LPWAN." *2021 5th International Conference on Computing Methodologies and Communication (ICCMC)* (2021): 453-459.

[9] Fig 8. Structure of LoRa 1278 Transceiver, Raghuveera, E. et al. "An IoT Enabled Air Quality Monitoring System Using LoRa and LPWAN." *2021 5th International Conference on Computing Methodologies and Communication (ICCMC)* (2021): 453-459.

[11] [12] [13] HARKAT, Mohamed-Faouzi & Mourot, Gilles & Ragot, José. (2006). An improved PCA scheme for sensor FDI: Application to an air quality monitoring network. Journal of Process Control. 16. 625-634. 10.1016/j.jprocont.2005.09.007.

[14] Radio Free Asia, *China holds five officials over 'falsification' of air monitoring data*, 27 October 2016, available at: https://www.refworld.org/docid/584811afa.html

[15]https://www.aei.org/wpcontent/uploads/2011/11/20060605_Schwartz.pdf?x91208

[16] Lotrecchiano N., Sofia D., Giuliano A., Barletta D., Poletto M., 2019, Real-time On-road Monitoring Network of Air Quality, Chemical Engineering Transactions, 74, 241-246.

[17][18] Sofia D, Lotrecchiano N, Trucillo P, Giuliano A, Terrone L. Novel Air Pollution Measurement System Based on Ethereum Blockchain. *Journal of Sensor and Actuator Networks*. 2020; 9(4):49. https://doi.org/10.3390/jsan904004

[19]https://uk.newsroom.ibm.com/2015-Dec-09-IBM-Expands-Green-Horizons-Initiative-Globally-To-Address-Pressing-Environmental-and-Pollution-Challenges