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Ambient Air Quality Monitoring In Dumping Ground Using Cyber Physical System

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***Abstract*— Air pollution is a problem for both environment and society. With the rapid growth in population and urbanization the waste generation has become a major concern and the economy will be severely impacted if not managed sustainably which will directly affect the ecosystem. This leads to adverse effects on the living conditions. Therefore, the quality of air should be monitored. There are many air quality monitoring systems but the goal is to have a device that is low cost, accurate decision making, can be used to thoroughly investigate the key elements of various city initiatives to reduce the concentration of primary pollutants in urban areas and monitor air quality. The air quality index(AQI) can be used to measure the quality of air. The main motive is to provides an economical way to measure crucial factors of the environment based on a low-cost sensor array with built-in amperometry and various gas sensors. In this proposed paper we have surveyed different approaches that has been implemented, various parameters considered and different algorithms used to predict the air quality in an approach to find the best suited way that can be implemented in the most polluted area like landfills. Overall, to provide an outlook on different approaches adopted with the array of parameters used and to choose the most appropriate prediction algorithms.**

***keywords*—Air quality monitoring, Air Quality Index (AQI), Cyber Physical System.**

I. Introduction

When it comes to human health, clean air is the most basic good. Poor air quality today is one of the leading causes of a variety of serious health problems. Vehicle emissions, industrial hazardous gas releases, and rising levels of dangerous gases and particulate matter all contribute to the pollution of the atmosphere. Levels of pollution are rising rapidly due to factors that can affect human health, such as industry, urbanization, population growth, and the use of automobiles. One of the most crucial criteria is the concentration of particulate matter, It substantially adds to the growth of air pollution. In order to quickly make the right judgments, this necessitates the measurement and analysis of air quality monitoring data in real-time. This paper introduces different stand-alone real-time air quality monitoring systems. The Internet of Things is now widely used in all industries. The loT in the project allows to monitor pollution levels from anywhere using your computer or mobile phone. The setup shows the air quality in PPM, which makes it very easy to monitor. monitor pollution levels from anywhere using your computer or mobile phone. The air conditioner is very dirty. In recent years, automobile exhaust, factory chemicals, smoke and dust have become ubiquitous. Therefore, the air conditioner is heavily polluted. The effects of air pollution are very bad for our health, especially where the air in our body is used for breathing. Some illnesses, such as asthma, cough, and lung disease, can occur in our lungs. Air pollution cannot be recognized by human emotions. Air pollution can contain many harmful substances such as LPG, carbon monoxide, and methane. Substances in polluted air are extremely dangerous.

II. Overview of Communication Technologies

1) The Internet of Things employs a variety of technologies and communication protocols. Bluetooth, WLAN, wireless protocols, LTE-A, and WiFi-Direct are among the most significant Internet of Things technologies and protocols (IoT communication protocols).
2) A crucial IoT communication protocol or technology. Bluetooth has grown to play a significant role in the computer and numerous consumer product industries. It is anticipated to be crucial, particularly for wearable products. Smartphones are frequently used to connect wearable devices to the IoT. An essential protocol for Internet of Things applications is the new Bluetooth Low-Energy (BLE), also known as Bluetooth Smart at the moment. It's important to note that it is intended to use considerably less power while offering Bluetooth's range.
3) Similar to Bluetooth, ZigBee is mostly utilised in industrial settings. It offers low power operation, high security, robustness, and high performance in complex systems, and is ideally suited to rely on wireless control and sensor networks in IoT applications. The most recent version of ZigBee is 3.0, which was just made public. In

essence, it combines many ZigBee wireless standards into one standard.

4) A low power RF communication IoT technology called Z-Wave was created particularly for home automation goods like sensor and lamp controls. Z-Wave has a simpler protocol than other protocols, which speeds up and simplifies development, however it only has one chip vendor, as opposed to several sources for other wireless technologies like ZigBee. Sigma Designs is this.
5) One of the most often used IoT communication protocols is WiFi connectivity, which is frequently a natural choice for many developers, especially considering the accessibility of WiFi in residential situations within LANs. It can manage enormous amounts of data and has a variety of current infrastructure, high-speed data transfer, and large data handling capacity. Currently, 802.11n is the WiFi protocol that most homes and businesses utilise. It offers a variety of several hundred megabits per second. This works well for file transfers, but many IoT applications may find it to be too power-intensive.
6) For Internet of Things (IoT) applications that need long-distance operation, cellular connection over GSM, 3G, and 4G can be employed. Although cellular can deliver enormous amounts of data, especially over 4G, the cost and power consumption can be prohibitive for many applications. It works best, though, for sensor-based data projects that send a tiny amount of data over the Internet at low bandwidth.
7) An Internet of Things (IoT) technology is NFC. This makes it possible for electronic devices to communicate easily and securely with one another, especially smartphones, enabling customers to complete transactions without having to be physically present. aids consumers in connecting their electronic gadgets and accessing digital material. In essence, it increases the capabilities of contactless card technology by enabling data interchange between devices at a distance of less than 4 cm.
8) For WAN (Wide Area Network) applications, LoRaWAN is one of the most widely used IoT technologies. With the capabilities that are specifically required to allow low-cost mobile secure communications in IoT, smart cities, and industrial applications, LoRaWAN is created to give low power WANs those features. In particular, it satisfies the demands for low power consumption and supports massive networks with a huge number of devices. There is a 0.3kbps to 50kbps data rate range.

IoT Technology	Standard	Power Consumption	Network Type	Speed	Range	Frequency Spectrum	Mesh
Bluetooth (BLE)	IEEE 802.15.1	10 mW	PAN	1 Mbps	50 m	2.4 GHz	No
ZigBee	IEEE 802.15.4	Very Low	PAN	250 Kbps	100 m	2.4 GHz	Yes
Z-Wave	Z-Wave Alliance	Very Low	PAN	100 Kbps	30 m	908.42 MHz	Yes
6LoWPAN	IEEE 802.15.4	Very Low	PAN	250 Kbps	10-100 m	2.4	Yes
Wi-Fi	IEEE 802.11	High	LAN	100- 250 Mbps	100 m +	2.4 GHz / 5 GHz	No
LoRa / LoRaWAN	IEEE 802.15g	High	LPWAN	27 Kbps	10 km +	470-510 MHz (China) 865-925 MHz	No
WiMAX	IEEE 802.16	N/A	MAN	70 Mbps	50 km	2–11 GHz	No
GSM/GPRS	ETSI	Very High	WAN	Moderate	35 km +	850 MHz / 1.9 GHz	No
LTE	3GPP	Very High	WAN	0.1 – 1 Gbps	28 km / 10 km	700–2600 MHz	No
LTE-M	3GPP	Moderate	LPWAN	1 Mbps	Long	Various	No
NB-IoT	3GPP	Moderate	LPWAN	250 Kbps	20 km +	Various	No

Fig 1: Comparison of different communication technologies.

III. Related Work

In [1], the authors have presented a research study to understand Information on environmental variables and also allowing easy integration into any other type of internet-based architecture (IoT) which allows the use of sensors capable of collect information on sensors related to smart city environment measurements, with a view to providing data on which environmental pollution-related information.

In [2], The author proposes a system that supports the potentially dangerous risks associated with landfill and waste management. The author used the concept of transfer learning to perform garbage detection and used a convolutional neural network for this task. The system provides a powerful automatic fire detection and extinguishing system and a toxic gas detection system that can be installed in various locations in landfills. The trash level can also be monitored by installing the proposed trash level sensor in the trash can.

In [3], The author proposed a system that could be installed anywhere in the city, local market, or industry. IoT-based air quality / pollution and particulate matter (PM) monitoringsystems provide pollutant levels in selected areas, data are uploaded to the Thingspeak cloud, and information is easy for people to inform about air quality. To be accessible and recognizable. And pollutant levels in their area. The portability of the system allows it to be installed anywhere in the city, local market, or industry.

In [4], the author proposed a model that includes the integration of a bidirectional recurrentneural network (RNN) that processes air pollution prediction and modelling in a timely manner as needed. This includes neurons that are themselves connected to implement a circular structure in the network. RNNs process both current and past inputs to monitor the quality of air pollution detection. Time dependencies are handled directly.

In [5], the author summarizes several methods for examining air quality. First, we classified air quality monitoring using big data methods into three categories: spatial model, temporal model, and spatiotemporal model. Next, we categorized big data technology air quality monitoring into three categories: statistical prediction models, deep neural network models, and hybrid models. They then analyzed and compared several typical air pollution trackingmethods. Finally, the outlook for the future of air quality analysis.

In[6], author proposed a simple model of a low power real-time air quality monitoring system. The system integrates a single-chip microcontroller, multiple calibrated air pollution monitoring sensors (for PM10, NO2, CO, PM2.5, SO2, O3, VOC, CO2), a LoRaWAN module for communication, and an online platform. Some measurements have warnings and this application can lead to the replacement of certain components of the exhaust system.

In [7], The authors found six significant air pollutants: ozone (O3), particulate matter (PM2.5), carbon monoxide (CO), nitrogen dioxide (NO2), sulfur dioxide (SO2), the most common. We have proposed a system to analyze health threats. They used fuzzy cMeans clustering to process polluted atmospheric data from the sensors. From the results, the authors conclude that the fuzzy c-means algorithm gives better results in terms of parameter accuracy, comparing it to other algorithms in the literature.

In [8], the authors state that most machine learning algorithms do not disclose the reliability and reliability of measurement results, but the Bayesian model provides an integrated validity check for the predictions. This publication uses laboratory and published field data to evaluate the potential of variational Bayesian linear regression and variational Bayesian neural networks for low-cost gas sensor and sensor system calibration.

In [9], the author presented a low-cost wearable sensor for conducting measurement campaigns using sensors to demonstrate the effectiveness and usefulness of citizen-based pollution measurement. The presented system successfully classifies the data indoors and outdoors and uses measurements from high-end reference monitoring stations to verify the consistency and accuracy of the data classified outdoors. The system also provides (i) detailed insights into air pollution across large geographic areas, (ii) identifying possible causes of air pollution depending on the region, and (iii) individualizing citizens about air pollutants. Prove the effectiveness of your campaign by providing insights into. Their dailycommute.

In [10], the author reviewed the design and development of the Mega Sense Cyber-Physical System & # 40; CPS & # 41. For spatially distributed IoT-based monitoring of urban air quality. Mega Sense can create aggregated privacy-aware maps and historical charts of collected pollution data. It provides a feedback loop in the form of personal information about outdoor and indoor air pollution, allowing citizens to take action to avoid future exposures.

In [11], the author proposed the AirQ platform. This is a smart and cost-effective solution for monitoring air quality. AirQ devices are portable, cost-effective and provide real-time,location-specific air quality data. Supports wireless data communication technologies such as WiFi, 4G, Bluetooth and LoRa. The author has developed an ontology-based back end that supports data management and the implementation of intelligent data analysis algorithms. Real-time air quality data and alerts are provided by the AirQ dashboard and smartphone app.

IV. Air Pollution Knowledge And Promising Technologies

A. *Air-Pollution Knowledge*

The pollutant emission factor is presented as a representative number intended to link the activities involved in the release of the pollutants with their quantity emitted into the atmosphere. smoke produced by solvents such as paints, hairsprays, varnishes, and aerosol sprays. These might be significant. In the 2010s, it was projected that emissions from these sources were responsible for over half of the volatile organic compound pollution in the Los Angeles Basin. These variables are frequently represented as the weight of pollutants divided by the unit weight, volume, distance, or time of activity that produces the pollutants (for Example, per ton of coal burned). Kilograms of emitted particle matter). These standards make it easier to estimate pollution emissions from different sources. These factors are typically simple averages of all accessible, acceptable-quality data, and are regarded as representative of long-term averages.

1. Carbon Dioxide (CO2): It is referred to as the "primary pollutant" and the "worst climate pollutant" because of its function as a greenhouse gas. The human respiratory system also releases carbon dioxide, which is a component of the atmosphere that occurs naturally and is necessary for plant growth.
2. Sulphur Oxide (SO2): Specifically sulphur dioxide, a chemical compound of formula S02. Volcanoes and a number of industrial operations both produce SO2. Sulphur compounds, which are burned to form sulphur dioxide, are frequently found in coal and petroleum. Normally, acid rain results when SO2 is further oxidized in the presence of a catalyst like NO2.
3. Nitrogen Oxides (NOx): When materials burn at high temperatures and during thunderstorm discharges, nitrogen oxides, especially nitrogen dioxide, are emitted. They can be identified as a dome-shaped brown haze or as a wind cloud hovering above the city. Nitrogen dioxide is a substance with the chemical formula NO2.
4. Carbon monoxide (CO): CO is a poisonous gas that has no color or smell. a thing produced through the burning of fuel like coal, wood, or gas. The majority of the carbon monoxide released into the atmosphere comes from vehicle exhaust. It causes smog-like airborne formations that have been linked to numerous pulmonary conditions as well as environmental and animal illnesses.
5. Volatile Organic Compounds (VOCs): VOCs are well-known outdoor contaminants. Methane (CH4) or non-methane are the two categories in which they fall (NMVOC). Methane is an extremely effective greenhouse gas that increases global warming. Due to their ability to create ozone and prolong the atmospheric lifetime of methane, other hydrocarbon VOCs are significant greenhouse gases as well.
6. Ammonia: Primarily produced from waste from agriculture. A substance with the chemical formula NH3 is ammonia. Typically, it is produced as a gas with a distinctively strong smell. Ammonia serves as a precursor for food and fertilizers, which greatly helps terrestrial organisms meet their nutritional needs.
7. Smell: as in sewage, waste, or industrial operations. Radioactive
8. contaminants: produced by natural phenomena such radon radioactive decay, nuclear explosions, nuclear accidents, and warfare explosives.

B. *Air-pollution levels*

The degree of air pollutants and the ensuing fitness danger growth with growing AQI values. As an illustration, an AQI rating of fifty or much less shows healthful air exceptional, while one in all over three hundred shows unsafe air exceptional. An AQI cost of a hundred for every pollutant usually equates to a degree of ambient air attention that meets the short-time period countrywide ambient air exceptional popular for the safety of public fitness. In general, AQI degrees of a hundred or much less are taken into consideration to be good. Air exceptional is dangerous while AQI values are above a hundred; first of all for a few susceptible agencies of people, then as AQI values upward thrust for everyone.

Agent Emitted	Net Change in Radiative Forcing in 2005 due to Emissions 1750 – 2005 (Wm^{-2})	Atmospheric Lifetime	Primary Sources
CO_2	1.56	Centuries-Millennia	Fossil fuel burning, deforestation and land use change, cement production.
CH_4	0.86	12 years	Landfills, natural gas leakage, agriculture.
N_2O	0.14	114 years	Fertilizer use, livestock sector, fossil fuel combustion.
CFC / HCFC	0.28	100 – 1000 years	Aerosols, cleaning products and refrigerants.
CO / VOC (O_3 precursor)	0.27	CO – months VOC – hours (O_3 – days)	CO – incomplete fossil fuel combustion; VOCs – petroleum production and consumption, solvents.
Black Carbon	0.44 – 0.9	1 week	Fossil fuel combustion, biomass burning.

C. *Air Quality Sensors*

A tool used to identify airborne contaminants is an air quality sensor. This comprises substances that can be hazardous to human health, such as particles, contaminants, and poisonous gases. They are employed in processes including air quality monitoring, industrial gas detection, combustion management, and oxygen generators for airplanes. A home fire alarm is a typical tool for detecting airborne particles. Ionization detectors and photoelectric detectors are the two types of sensors used to detect smoke. The ionization sensor makes use of a tiny radiation source that continuously emits alpha particles. Small leakage currents between the electrodes are blocked when smoke particles reach the ionization chamber.

When this is discovered, an alert will go out. Air quality may be tracked using dust sensors. To find the light reflected by dust particles, they employ a phototransistor, a pair of infrared diodes, and a pair of diodes. They are excellent cigarette smoke detectors that can differentiate between smoke and home dust using reflected energy patterns. Air conditioners, monitors, and air purifiers all contain them. There are numerous ppm detection ranges for CO2 gas sensors. Non-dispersive infrared (NDIR) is used to identify the sensor's presence. HVAC systems make use of them to deliver demand-controlled ventilation (DCV).

Two chemical substances can be measured electrochemically by a single Air gadget. Two gas cells that are installed in the sensor's measurement module provide readings. Every sensor has a light diode that changes colour to display the current air quality using colour signals that correspond to the CAQI or AQI scale.

V. Air Quality Systems

In this section, we present an investigation into AQ systems based on different technologies.

a) Based on Machine learning technologies

In order to warn users about hazardous situations, machine learning is utilized to predict the AQI of a given area. As a result, you have enough time to put on a mask or employ the system-wide architecture's air filtration system. It is a Wi-Fi capable micro system with wired connections to a GPS module, a MQ2 flammable gas and smoke detection sensor, a MQ9 carbon monoxide and methane detection sensor, a MQ9 ammonia sulphide sensor, and a MQ9 benzene steam detection sensor. It consists of a detection sensor (MQ-135), a flame sensor, an LPG, methane, and butane sensor (MQ6). Mobile apps and web servers are also available. Each gas sensor gathers various gas properties and transmits them to the web server in the background. then employs the SVM on the back-end web server.

The SVM method forecasts regional AQI based on atmospheric gas concentrations and weather forecast data from smoke and gas detectors. The supervised machine learning algorithm known as SVM can be applied to classification or regression issues. In order to discover the best boundaries between the outputs based on those changes, I utilised SVM to alter the data using a method called kernel tricks. Users will be alerted to suitable risks as needed when the projected AQI is predicted. This enables users to act quickly to avoid danger. Using the system's GPS module, a precise location is linked to the projected AQI.

Fig. 1. Magnetization as a function of applied field.

b) Based on indoor AQ System

The AQI measures how clean or dirty the air is and what effect it has on human health. AQI concentrates on health impacts that may appear hours or days after breathing contaminated air [4]. Five key air pollutants—ground-level ozone, particulate matter, carbon monoxide, sulphur dioxide, and nitrogen dioxide—are used by the Environmental Protection Agency (EPA) to compute the air quality index. It is quantified in PPM (parts per million). For each of these contaminants, the EPA has developed national air quality standards to safeguard public health, as seen in the figure. 2. Equipment that can track air pollution and the worsening of air quality and offer remedies is needed to address this issue. By constantly tracking particle matter and air quality and taking action when thresholds are surpassed, our gadgets offer smartphone and PC solutions. The installation of this gadget is flexible and it is simple to operate. The environment, the general people, and the government become intertwined as a result. In addition to measuring the air quality index in PPM (parts per million), our equipment also detects the concentrations of particulate matter PM1.0, PM2.5, and PM10 in lg/m3 (micrograms/cubic metre). It is indisputable that all of these environmental variables are present because PM concentration and the air quality index are affected by variables including humidity, dew point, humidity, temperature, and barometric pressure. All of these aspects were taken into account by the suggested system for the gadget. Temperature, humidity, pressure, and dew point are negligible, but it is very important to understand that air quality changes as temperature and humidity change. When the temperature is high and the humidity is low, you will find that the air is too dry. However, when the humidity is increased, the air becomes moist and clean. Our device can also measure temperature, humidity, barometric pressure, dew point, and estimated height above sea level.

c) Based on big data analytics techniques

Air monitoring, air quality forecasting, and air pollution traceability are the three steps taken to solve air quality issues. · An evidentiary base for air quality predictions and traceability is provided by air quality monitoring, and more precise monitoring data can result in more accurate air quality predictions. Big data in cities can be categorized as static data, spatiotemporal dynamic data, and temporal dynamic spatial data, according to research on urban computing. According to the spatial, temporal, and spatiotemporal properties of the measurement station data, these approaches can be divided into three categories: spatial model, temporal model, and spatiotemporal model. Additionally, data fusion makes it simple to collect spatiotemporal correlations of data, providing big data technology models with a more precise grasp of. You can use these methods to enter missing values in the air quality data to ensure the quality of the monitoring data. · Air quality predictions are critical to improving air pollution and strengthening urban pollution control and early alert management. Based on numerous studies on air quality prediction using analysis methods using big data methods, this paper classifies air quality prediction methods into three categories: statistical prediction models, deep neural network models, and hybrid models... Such predictive models based on big data technology generally require large amounts of data, and data fusion processes this data with multi-source non-uniformity, dynamic variability, and spatiotemporal correlation characteristics. Is a practical way of Government organisations may create fast and accurate air pollution management plans with the help of air pollution traceability, and they can take the necessary actions to cut costs and reduce losses. Traceability methods for air pollution can be classified into two categories based on how big data technologies are combined with them: data-driven models and conventional models. The air quality traceability technique involves data fusion. This makes it possible for big data technology-based models to unearth more useful data and locate pollution sources as rapidly as possible.

d) Based on big data analytics techniques

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e) Based on data analytics algorithms

AirQ's PM2.5 sensor uses laser scattering to estimate PM2.5 concentration. However, this technique is sensitive to humidity. Therefore, PM 2.5 sensor readings tend to be higher than the actual values measured by EPA rated equipment. Therefore, we have developed a data analysis algorithm for adjusting PM2.5 data generated by AirQ. We deployed AirQ devices at the Singapore National Environment Agency (NEA) air quality station and compared the accuracy of AirQ PM2.5 data with the accuracy of the NEA air quality station. NEA publishes hourly delay averages of PM2.5 measurements from AirQualityStation. Using two AirQ devices, we derived a similar hourly delay average from PM2.5 measurements. Pearson's product moment correlation coefficient r between two different sets of AirQ PM 2.5 data was calculated to determine their degree of correlation. The results show that the PM 2.5 data from the two AirQ devices are very consistent and well correlated with each other. r (AirQ1, AirQ2) = 0.9952 PM2.5 data from two AirQ devices also correlates fairly well with data from NEA stations. : R (AirQ1, NEAEast) = 0.593 r (AirQ2, NEAEast) = 0.620 Sensor data calibration that improves the correlation between PM2.5 data of AirQ and PM2.5 data of NEA station by using the effect considering humidity. I have developed an algorithm. A calibration equation was derived based on a preliminary linear regression model and fitted to AirQ PM 2.5 data to improve correlation with NEA station data. The format of the calibration equation is: NEWAirQ = a * (ORIG AirQ) + b * Humidity + c where a, b, and c are constants. We implemented a linear regression model solution to get the optimal values for a, b, and c, thereby obtaining the calibration equation. You can use the linear calibration equation to calibrate the AirQ dataset and improve r (NEW AirQ1, NEAEast) to 0.739. Figures 3 and 4 show AirQ data before and after calibration. From these figures, it is clear that the AirQ dataset is more closely correlated with the calibrated NEA dataset. However, more data acquisition and more advanced modeling are required to improve the accuracy of calibration equations. We will also develop other data analysis methods to derive air quality information, discover trends and predict changes in air quality. These techniques will enable the AirQ platform to provide real-time and location-specific alerts and forecasts for air quality events.

f) Based on data accuracy and energy management

Data loss and data corruption can really be caused by unforeseen occurrences including equipment breakdowns, routine maintenance, subpar transmission, and extreme weather conditions (noise, runaway, etc.). Further analysis is hampered by missing data and errors. As a result, inaccurate data and data loss present a serious challenge to reliable monitoring. Despite numerous methods for filling in gaps in the data and cleaning it up, data monitoring is challenging. Data can be gathered and cleaned up in a variety of methods, and several external components can be used to enhance air quality monitoring. Swarms of unmanned aerial vehicles are used by the authors of [89] to monitor and anticipate the spatial and temporal distribution of air quality indexes using a lightweight, associative learning-based air quality assessment system (UAVs)... The Gaussian process was suggested by the author of [90] as a method for estimating the AQ. Unsteady (NS) kernel for input-dependent adaptive smoothness. Hamming a kernel for category features based on distance. Additionally, this method is characterised by a locally periodic kernel for temporal periodicity. The author was able to scale the method to very large amounts of data by using batch training. The proposed approach is inferior to accepted benchmarks and neuro-attention-based techniques. In [91], the author identified a duplicate station and offered a fresh method for deciding between options in AQ. This makes it easier to put in place precise air quality management measures. They first used stepwise regression and correlation analysis to discover overlapping stations. To locate the corresponding alternative stations, they used cluster analysis and correspondence analysis. Finally, support vector regression is used to verify the outcome of the optimization process. To evaluate the framework, Shanghai AQ is utilised. This study's methodology can be applied in other cities and regions to enhance the reliability of pollution data and reduce pollution. A novel hybrid deep learning model was developed by the author of Output Tracking [92] for hourly PM2.5 contaminant prediction, and accuracy and delay in edge devices were assessed. horoscope PM2.5 forecast. With the Raspberry Pi Model B, the suggested approach is designed to function best. For managing energy usage and AQ system utilisation, a number of techniques and procedures are offered. The author first introduced IoT and WSN systems in [94], which are capable of supplying real-time air quality data while also saving energy. Authorities can manage and safeguard the environment more effectively as a result. were simulated with regard to energy use, energy savings, duct air supply, and indoor air quality (IAQ).

Smart administration and monitoring are made possible by IoT and WSN. Improve community services while educating others and being active. Capabilities and scope of existing solutions are too limited. The proposed system makes use of the LoRa module. A lot of the current wireless communication methods are outperformed by this LPWAN technology. The suggested system is made up of sensors, wireless LoRa modules for sending and receiving sensor data, and the ThingSpeak IoT platform for processing and visualising sensor data. The authors of [95] have created a multiparametric sensor node for air quality monitoring that is powered entirely by environmental energy and can run continuously without a battery or human intervention. For both indoor and outdoor applications, the device can monitor air quality levels in "set and forget" settings. With the help of this technology, measurements of air quality may be reported and tracked accurately. Sigfox's extensive radio range is why the author of [97] chose it. With a little more power, this is essentially comparable to a cellular network. With extremely low power consumption and a star network architecture appropriate for short-distance communication with Sigfox gateways, the authors have created a Sigfox-based heterogeneous network design. The author claims that this kind of architecture ensures extensive end device coverage and extended battery life after conducting multiple experiments utilising energy modelling (up to 4 years). The effectiveness of ventilation. (Indicated by the amount of CO2 present in the space.) On-off action may have an impact on durability and IAQ. Evolutionary algorithms can be used to decrease pointless off-off operations and raise the maximum and lower bounds of concentration. The example study demonstrates that this modification enhances breathing at low doses. Mechanical ventilation with a fixed capacity is wasteful and distracting. Demand-controlled ventilation leads to increased longevity and indoor air quality. The author in [99] proposed and experimented with the installation of heat pipe heat exchangers in air conditioning systems. We modelled the impact of heat pipe heat exchangers on energy use, energy savings, air supply, and indoor air quality in air conditioning systems (IAQ).

VI. TYPES OF AIR QUALITY SENSORS

1) Electrochemical Sensors

$ME4$ – H2	O2
$ME4$ – H2S	H2S
ME3-CL2	Chlorine
ME3-NH3	Ammonia
ME3-SO2	SO2
TGS2442	CO
TGS416	CO2
T6713	CO2

2) Semiconductor Sensors

MQ-9B	CO, Combustibles
MQ-6	LPG, Propane
MQ303B	Alcohol
MQ-4	Natural gas, CH4
MQ-5B	LPG, Natural gas, Coal gas
MQ-7	CO
MQ131	O3
MQ-2	C4H10, C3H8 , Alcohol, CH4 , H2 , CO

3) Light-Scatting Sensors

1528-2509-ND	PM1,2.5,10
B5W-LD0101	PM0.5,2.5
ER-PM3003	PM1,2.5,10
SPS30	PM0.5,1.0,2.5,4,10
SM-UART-04L	PM2.5,10
PMS7003	PM1.0,2.5,10
480-7035-ND	PM2.5,10
OPC-N2	PM1,2.5,10

4) LoRaWAN for AQ monitoring

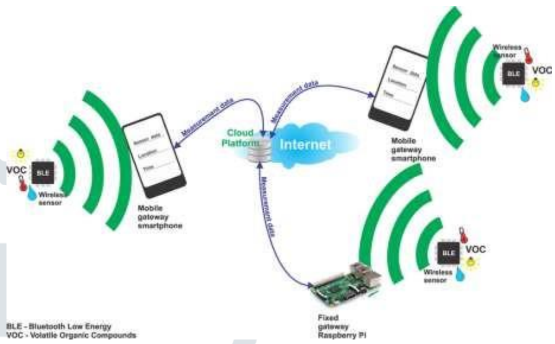

Fig 2. LoRaWAN for AQ architecture

In order to gather timely data on air quality and provide updates in the cloud, this study suggests a smart long-distance (LoRa) sensor node. The developed LoRaWAN-based Internet of Things (IoT)-based air quality monitoring system (hereafter referred to as LoRaWAN-IoT-AQMS) is employed in outdoor contexts for verification. Its effectiveness and reliability were put to use. The system includes several sensors (including NO2, SO2, CO2, CO, PM2.5, temperature, and humidity), an Arduino microcontroller, a LoRa shield, a LoRaWAN gateway, and the Internet of Things (IoT) platform The Thing Network (TTN). With a solar charger and a photovoltaic solar panel, the LoRaWAN-IoT-AQMS is an independent system that runs sustainably on a rechargeable battery. In order to get thoughtful data about air quality, our system is simultaneously using an intelligent sensor unit. The system subsequently sends the data across the gateway to the TTN platform that has been linked with the ThingSpeak IoT server. During this process, the data that has been gathered is updated, and the data is shown via the Virtuino mobile application in a web-based dashboard and graphical user interface that has been created (GUI). This makes it simple for the user to obtain the displayed information using a smartphone. By contrasting the trial results based on the cutting-edge Aeroqual air quality monitoring equipment with the results from the created LoRaWAN-IoTAQMS, the results are validated.

VII. TECHNICAL LIMITATION

The Internet of Things (IoT) combines several modern technologies (sensors, actuators, semantics, service management, context-aware computing, big data analytics, communication technologies, etc) to produce innovative, transformative new solutions. To do. this planet. The technology allows for both indoor and outdoor AQ detection. Additionally, the data may be supplied inexpensively to remote individuals, guaranteeing that they are continually cognizant of the environment's physical state in the present.

As a result, it specifies a few technological limitations from an architectural standpoint.

1) Data volume and non-uniformity: how much and what kind of visual information a person can process. Data can be constantly gathered over a predetermined length of time (time trigger) or when a specific event takes place (event trigger). Data gathered from diverse sources can either be unstructured, semi-structured, or structured.
2) Dynamics: displays the frequency of position changes made by a sensor at a specific location. By measuring a gas line sensor, it is possible to determine the precise position of a gas leak. For instance, you may monitor areas like gas pipes and rooms in buildings with high levels of AQ using RFID (Radio Frequency Identification) tags.
3) Consistency: combines the 3D model and other priorities with the field's sensor feed.
4) Context Awareness: According to the IoT perspective, the creation of new techniques, models, approaches, and middleware solutions adds knowledge and value to the raw data collected. Develop business-critical information from sensor data, connect it with other data to create new knowledge for smarter communication and interaction, and present it in a visually appealing, intuitive interface.
5) Data-driven design: based on compiled data, offers visual feedback to the field.
6) Human-model interaction: Enhancing user ease through the design of high-performance apps with complex interfaces and straightforward services
7) Security and Privacy: and private systems demand secrecy, dependability, and nonrepudiation. So improving the security and privacy of your system by employing methods to counter hazards including data theft, fraud, internal crime, and sabotage.
8) Energy management: You must employ low power technology to lower energy consumption and increase the lifespan of your network. To increase energy efficiency, numerous doable strategies and strategies are now accessible.
9) Fault Tolerance: This is the capacity to sustain the dependability of different system components and keep them maintaining uninterrupted operation by providing a particular level of availability and performance tailored to the needs of a particular application. IoT solutions' fault tolerance is determined by the IoT architecture. As the central module has access to all data and only needs one redundant central module, this process is simple with a centralised IoT design. On the other hand, data flow detection techniques are necessary for fault tolerance in distributed architectures.
10) Real-time view: To enable emergency response via the IoT, data processing and transmission must be done in real-time. Many IoT devices and connected items can produce multiple concurrent events.

VIII. Conclusion

Through this survey paper, we discussed a study on air quality monitoring techniques from the perspectives of the various contaminants, types of air quality sensors, and various air quality systems adopted. We also presented a study on the types of air quality sensors, different computing technology concepts, and different techniques used. The use of Cyber-Physical System technology enhances the process of monitoring numerous environmental factors that have been attempted and discussed in the literature. Overall, the study presents the many methods used for measuring air quality, the factors taken into account, and provides a framework for future research in this field.

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