Cloud-Enabled Air Quality Monitoring and Control System

*

***Abstract*—The air we breathe is worsening due to urbanization, industrial activity, and advancing technologies. Air quality management aims to address these issues, benefiting both the environment and public health. This is a crucial concern for the present and future, as poor air quality impacts everyone, regardless of location or socioeconomic status. To tackle this problem, it's essential to identify pollution sources, consistently monitor air quality, and implement enforceable regulations. Collaborative efforts are needed, along with continuous research and innovation to find effective solutions. This introduction highlights the importance of air quality and the challenges associated with managing it, hoping to raise awareness and inspire collective action for cleaner air**

***Index Terms*—IoT, AWS, Cloud, Management**

I. Introduction

The quality of the air we breathe has become a crucial global problem in a time of increased urbanization, industry, and technological development. In order to address the numerous problems caused by air pollution, air quality management, a multidisciplinary field at the confluence of environmental science, policy, and public health, has assumed a prominent role. The goal of this intricate and developing field of study is to protect not just the environment but also human health and future generations. It is impossible to overestimate the significance of proper air quality control. From immediate health effects like respiratory ailments to long-term dangers like climate change, poor air quality has far-reaching effects. It is a global issue that affects both urban and rural communities equally, irrespective of socioeconomic level. Understanding the origins of pollution, monitoring air quality, creating and enforcing rules, and involving communities in the promotion of sustainable practices all play a part in this holistic approach to air quality management. To keep up with new pollutants and changing environmental conditions, it also calls for ongoing study and innovation. This introduction serves as a starting point for the investigation of air quality management by providing details on its background, present problems, and potential future directions. We will examine the science underlying pollution, the laws enforcing change, and the technology advancements paving the way for a cleaner, healthier future for everybody as we delve into the numerous facets of air quality management. As we set out on this journey, we hope that this resource will serve as an inspiration and educational tool for people, communities, and policymakers alike, encouraging a shared commitment to protecting the air we all breathe. .

II. Literature Review

Due to its potential to change the precision and timeliness of weather forecasts, air quality management has attracted a lot of interest recently. The essential elements, benefits, difficulties, and prospects connected with cloud-based weather forecasting are highlighted in the examined literature. The literature's major themes and conclusions include:

A. Cloud based decision support system for Air Quality Management

In the field of manage air quality, IoT-based handheld environmental and air quality monitor stations have become transformational technology. These portable instrument provide on-site, real-time measurement of air pollutant, allowing for deeper comprehension of source and trend of localized pollution. The literature emphasize how adaptabl, affordable, and user-friendly it is, making it an essential resource for both researcher and the general public. This tool also make it more easier for citizen to participate in effort to monitor air quality, giving community more ability to promote clean air. They have potential to close data gap, raise public awareness of pollution, and enable data-drive policy choice for better air quality.

B. An IO T-Based handled environmental and air quality monitoring station

In the field of managing air quality, IoT-based handheld environmental and air quality monitoring stations have become transformational technologies. These portable instruments provide on-site, real-time measurements of air pollutants, allowing for a deeper comprehension of the sources and trends of localized pollution. The literature emphasizes how adaptable, affordable, and user-friendly they are, making them essential resources for both researchers and the general public. These tools also make it easier for citizens to participate in efforts to monitor air quality, giving communities more ability to promote cleaner air. They have the potential to close data gaps, raise public awareness of pollution, and enable data-driven policy choices for better air quality.

C. NOAA's Global Forecast System Data in cloud for community Air Quality Modelling

An important development in the subject is the use of NOAA's Global Forecast System (GFS) data in cloud-based platforms for community air quality modeling. GFS provides thorough meteorological information necessary for precise estimates of air quality. It becomes more accessible and scalable when it is integrated into cloud environments, benefiting all stakeholders. There is room for precision and scope improvements in air quality models, according to research. Real-time data updates and collaborative modeling efforts are made possible by the utilization of the cloud. This strategy represents a positive advance in the development of more accurate, fine-grained air quality forecasts for better-informed decision-making and the preservation of public health.

D. Monitoring of Cloud-Based Air Quality using Node MCU

Using Node MCU in cloud-bases systems to monitor air quality are recent breakthrough that show tremendous promises for manage air quality. A open-source Io T platform call Node MCU make it possible to gathers real-time data and sends it to cloud server for continuously, remote air quality monitoring. The material emphasize it's affordability, expandability, and simplicity of uses. Additionally, Node MCU's interfaces with cloud platforms improve data accessibility and analysis, give stakeholders useful informations about change in air quality. With help of citizen-driven effort, academic researches, and policymakings, this technology have lot of promise to help develop more sensible method for combat air pollution and preserving public health. pollution and preserving public health.

E. An Intelligent IO T-Cloud Based Air Pollution Forecasting Model Using Univariate Time-Series Analysis

An important development in the management of air quality has been made with the creation of intelligent Io T-cloud-based air pollution forecasting models employing univariate time-series analysis. These models make use of the capabilities of Io T devices for the collection of data in real-time and cloud-based platforms for in-depth analysis. The research highlights their potential for enhancing forecasting accuracy for air pollution. These models improve prediction accuracy by taking historical data trends, climatic variables, and pollution concentrations into account. This technology has a wide range of uses, from early warning systems to improving pollution mitigation tactics, ultimately resulting in better management of air quality and improvements to public health.

F. Air Quality Monitoring Using Arduino and Cloud Based System in IoT

The devised system incorporates a range of sensors to measure diverse air components, including O3, SO2, CO, and particulate matter, all managed by an Arduino microcontroller. The intricate details of these sensors and their integration within the Arduino setup are comprehensively documented. The generated data is transmitted to a cloud-based infrastructure, which is accessible via a WiFi module integrated into the Arduino platform. Users can conveniently access the outcomes of this monitoring initiative through a dedicated web page hosted on the cloud platform.

G. Real-Time Air Pollution Monitoring Systems Using Wireless Sensor Networks Connected in a Cloud-Computing, Wrapped up Web Services

This study outlines a secure and cost-effective real-time air pollution monitoring system as a proactive approach to the escalating issue of air pollution. That poses a significant threat to global quality of life. Here, the proposed system's design and implementation adopts a three-layer architecture. Within the first layer, the sensors are connected to an Arduino platform. Which directs data to a data processing node (Raspberry Pi). Messages are dispatched using the Message Queuing Telemetry Transport (MQTT) protocol through wireless connectivity. The application layer is comprised of a cloud-based server hosting an MQTT Broker service. Which acts as a gateway for messages from the sensor layer. This information is then presented on a control panel via the NODE-RED service. That allows visualization of communication patterns and utilization of acquired data. MongoDB is used to store the data in the NoSQL database. A RESTful web service is established to facilitate the transfer of information for subsequent analysis of the data.

H. Wireless Sensor Network Combined with Cloud Computing for Air Quality Monitoring

The focal point of this paper is an innovative system for air quality assessment. Composed by interconnected sensor network deployed across various locations, forming a wireless sensor network (WSN). Built upon energy-efficient ZigBee motes, these sensor nodes transmit real-time measurements to a cloud-based infrastructure via a central gateway. Overall, it introduces an innovative air quality measuring framework utilizing wireless sensors. Particularly those of low-cost, that are organized in densely distributed networks. These networks offer heightened spatial resolution compared to conventional methods of monitoring ambient air quality. Within this architecture, an optimized cloud computing system has been developed to effectively store, monitor, process, and visually represent the influx of data stemming from the widespread sensor network. The cloud environment is leveraged to perform data analysis using artificial intelligence techniques. Which enhances the detection and understanding of various compounds and contaminants.

I. Cloud-Based Weather Forecasting: Improving Accuracy and Timeliness of Weather Predictions

The paper conducts a thorough study of existing literature, dissecting the fundamental constituents of cloud-powered weather forecasting. It is the implementation of cloud-based solutions within weather forecasting systems, aiming to amplify accuracy and timeliness. The research illuminates the manifold advantages of adopting cloud infrastructure. It highlights mainly about encompassing scalability, high-performance computing capabilities, and instantaneous access to real-time data. These attributes collectively contribute to the optimization of weather prediction models, strengthening their effectiveness. The study also appraises the challenges and prospects inherent in cloud-driven weather forecasting. Issues spanning data security, privacy concerns, and the integration of advanced technologies such as artificial intelligence and big data analytics are thoroughly examined.

J. IoT-Based Smart Air Quality Control System: Prevention to COVID-19

Exposure to polluted air exacerbates the impact of COVID-19, thereby elevating its mortality rate. When breathing in more polluted air, historical instances like SARS outbreaks and perilous respiratory infections highlight the amplified danger of mortality. Addressing this concern, a proposed solution involves an Internet of Things (IoT)-based intelligent air quality control system. That aims at curbing the community spread of viruses such as COVID-19. This innovative system relies on an array of air pollution sensors to assess air quality. It effectively detects the presence of air pollutants in the environment. The strategically is the positioning of sensors in both indoors and outdoors. The core objective of this initiative extends beyond human perception to draw attention to environmental issues and actively mitigate the spread of COVID-19. The system is further integrated with cloud technology to store the gathered data, enabling continuous monitoring and regulation of air quality. Rigorous testing validates the accuracy of this intelligent unit in monitoring air quality and seamlessly storing data on the cloud for diverse applications.

K. Wireless sensor network combined with cloud computing for air quality monitoring

The integration of wireless sensor networks and cloud computing to monitor air quality is probably the subject of the research paper with the title ”Wireless Sensor Network Combined with Cloud Computing for Air Quality Monitoring”. In such systems, sensors are often placed in various areas to gather data on air quality, which is subsequently sent to the cloud for archival, analysis, and visualization. The ability to analyze air pollution levels, identify trends, and give insightful data for environmental management and public health is made possible by this combination of real-time monitoring, data storage, and advanced analytics. The study probably goes into great detail about the technical features, advantages, and applications of this novel method of air quality monitoring.

L. Air quality monitoring system based on IoT using Raspberry Pi

An ”Air Quality Monitoring System Based on IoT Using Raspberry Pi” probably describes a system that uses IoT technologies and the adaptable single-board computer Raspberry Pi to monitor the quality of the air. A system like this would use sensors to measure different air contaminants, like particulate matter and gases, and send the information to the Internet. The computational power of the Raspberry Pi may be used to process and save this data, making it remotely accessible. This method contributes to environmental awareness, health monitoring, and urban planning activities by providing affordable, scalable, and configurable methods for tracking air quality in real-time.

M. Polluino: An efficient cloud-based management of IoT devices for air quality monitoring

The paper ”Polluino: An Efficient Cloud-Based Management of IoT Devices for Air Quality Monitoring” probably describes a system called ”Polluino,” with the goal of streamlining cloud-based management of IoT devices for air quality monitoring. The deployment and use of IoT sensors that detect air quality parameters are probably made easier by this approach. Utilizing cloud technology certainly centralizes data gathering, analysis, and visualization, facilitating real-time air quality monitoring and offering effective tools for environmental monitoring and decision-making. A system like this would help to regulate air quality better and raise awareness of the environment in metropolitan areas.

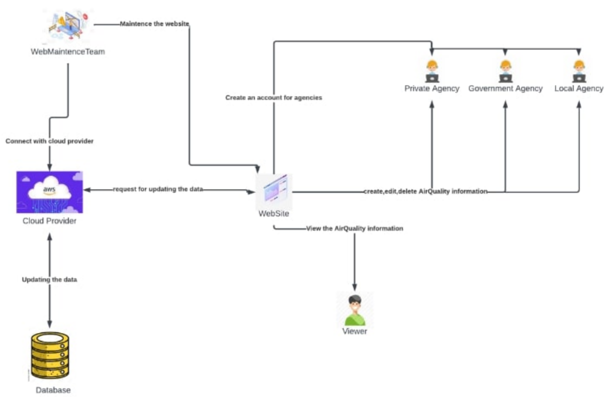
N. Design and implementation of LPWA-based air quality monitoring system

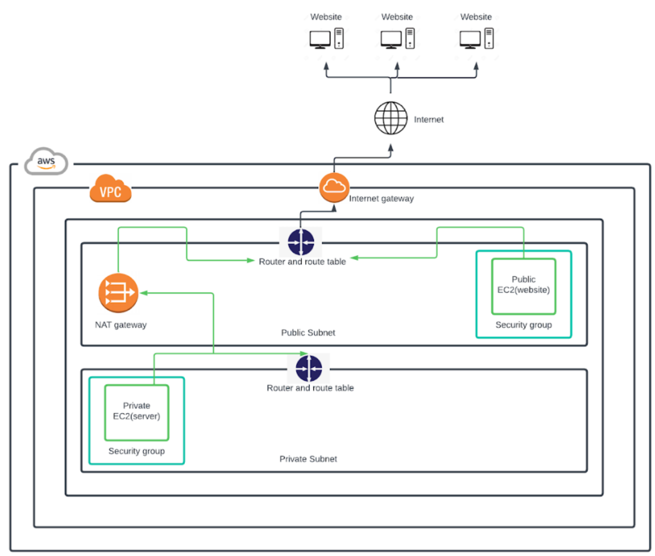
The creation and implementation of an air quality monitoring system based on Low Power Wide Area (LPWA) technology are probably covered in the paper ”Design and Implementation of LPWA-Based Air Quality Monitoring System”. Long-distance communication capabilities and energy efficiency are two advantages of LPWA networks. The use of low-power Internet of Things sensors in this system is expected to be used to assess air quality indicators including pollutants and particle matter. These sensors can communicate data effectively over long distances thanks to LPWA technology. The design, hardware, software, and advantages of this LPWA-based system, which improves air quality monitoring with longer device battery life and greater coverage, may be covered in full in the paper.

III. Methodology:

Effective management of atmospheric emissions, pollutants, and thorough monitoring of emission levels in the air are all important measures to safeguard the integrity of our environment. Within this context, a dedicated Air Quality Monitoring System plays a crucial role. To manage the air quality, the proposed system presented will serve several benefits. An essential factor is the identification of areas where the pollution level of the area is extreme. It will provide valuable insights that regulatory bodies can rely upon to ensure environmental standards are maintained. By providing information about air quality, this system will foster a sense of awareness among residents of those specific areas. This will enable individuals to make informed choices that will contribute to their well-being and the environment. As presented in diagram 1, the anatomy of the system can be divided into four parts. In the first section the data of air condition are collected through IoT devices. And stored in the local data servers. In the second segment, the data are validated by the government agencies and then is transferred to the AWS cloud servers. The third segment of the system is to maintain, analyse for proper visualization. In the final segment the analysed data are visualised through a website. The system takes the data of the air quality provided by the government third parties and analyses the data to visually represent the data in the form of graphs. The visual representations of the graph makes the data easy to understand and identify the nature of the pollutants, identify the source and potential threats. The data are collected by using Iot devices that can sense the presence of CO, SO2, O3 and other matters known to pollute the air. The data are stored in the local servers of the government agencies. And then verified by the officials the accuracy of the collected data is transferred to the system. The SQL databases are stored in the private instance and the UI design in the public instance. We can't access the private instance from any other local computer except from our public instance. That's why if we want to access in our private instance we must first access to our public instance then we can remotely connect the private instance from public instance For the system. In this instance we use the custom VPC (virtual private cloud) and set the IP range to 192.168.1.0/24 . Under in this IP range we created 4 subnets, two for public access two for private access. We use the first two subnet for public access which is 192.168.1.0/24 and 192.168.1.64/24. From this subnet We have 128 IP address for the public instance and 128-4 = 124 host we can achieve.Then we use the last two subnet for private access which is 192.168.1.128/24 and 192.168.1.192/24. From this subnet We have 128 IP address for the public instance and 128-4 = 124 host we can achieve.In this project as we used a custom VPC so that why we need to create a internet gateway for the public instance for routing the traffic from public instance to internet.And we use the Nat gateway to connect the private instance through the public subnet to the internet so we can execute our MYSQL database from the private instance and connect it to the public instance UI so that we can show the graph of the air quality in different places. In case of heavy traffic the system avails the Elastic IP service to avoid unavailability. An auto scaling group is maintained to provide instances in case of any failure. And then the SQL data are inserted in the instances. The data is analyzed and presented in the graph. The analyzed data visualized through graphs cab ne used by the different agencies and organizations for the research, making new policies and weather updates.

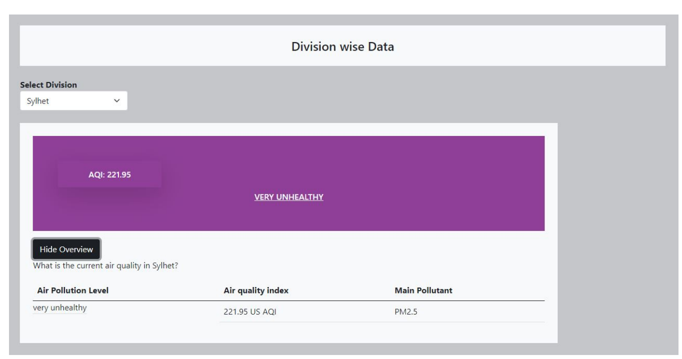
Diagram:



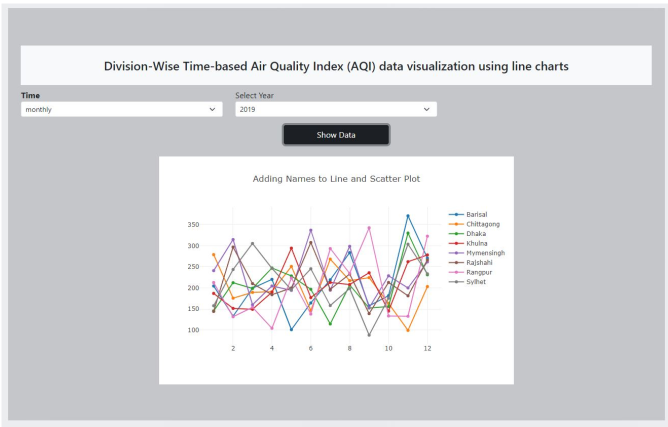


IV. Graph

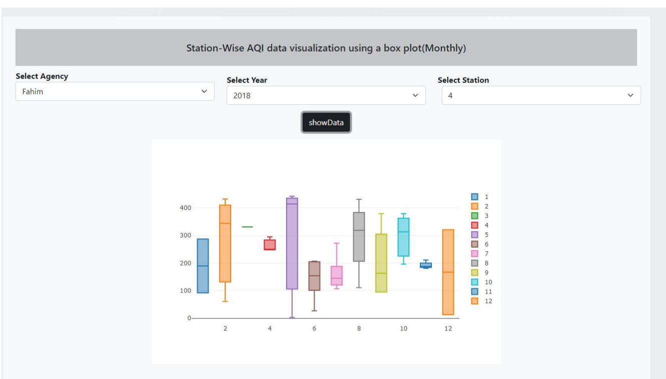
A. Division Wise AQI data



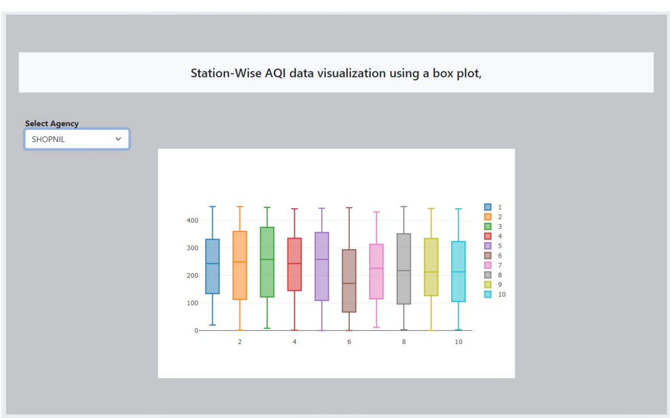
B. Monthly basis for all division based AQI data



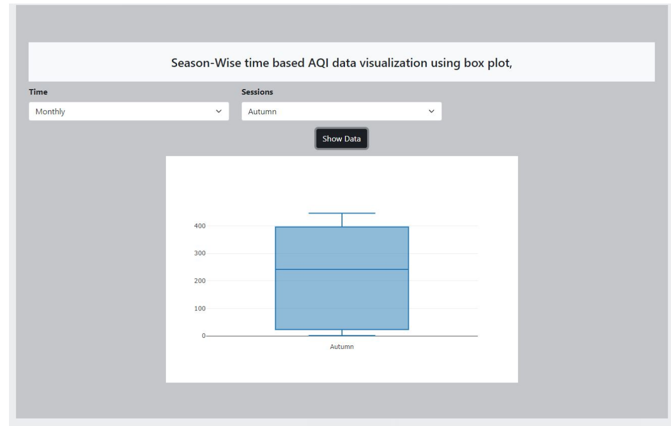
C. Specific Agent and the station based AQI data



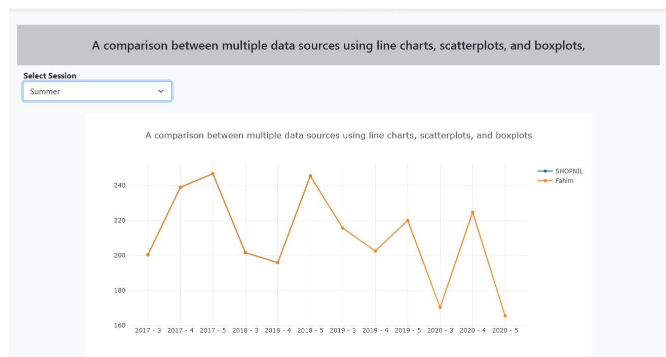
D. Specific Agent All Station based AQI data



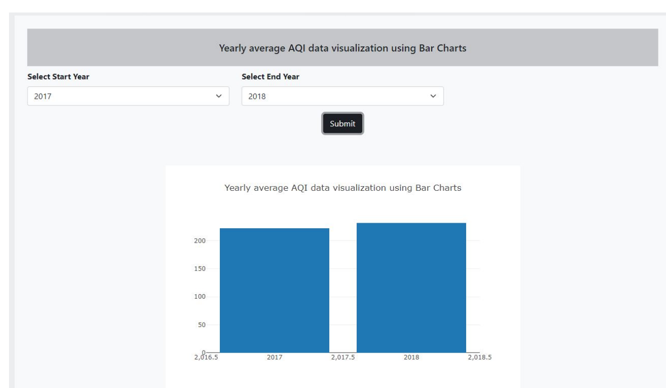
E. Season and time based AQI data



F. Season wise AQI data



G. Yearly avarage AQI data



V. Result and Analysis

A. Cost based on Hourly

2*0.0196= 0.0392 USD (For 2 Instances)
Elastic IP (Based on how much you use)
If additional users join our server, there will be a lot of pressure for auto scaling, and the cost would be: 5*0.0196= 0.098 USD (For Private Instance)
5*0.0196= 0.098 USD (for public instance) or
1*0.0196= 0.0196 USD(for public instance) or
1*0.0196= 0.0196 USD (for private instance)

B. Cost based on a cycle of 15 days

2*0.0196*24*15= 14.112 USD (This is applicable for 2 instances)
Elastic IP (Based on how much you use)
If additional users join our server, there will be a lot of pressure for auto scaling, and the cost would be: 5*0.0196*24*15= 35.28 USD(For private Instance)
5*0.0196*24*15= 35.28 USD(for public instance) or
1*0.0196*24*15= 7.056 USD (for public instance) or
1*0.0196*24*15= 7.056 USD (for private instance)

C. Cost on Monthly Basis

2*0.0196*24*30= 28.224 USD (This is applicable for 2 instances)
Elastic IP (Based on how much you use)
If additional users join our server, there will be a lot of pressure for auto scaling, and the cost would be: 5*0.0196*24*30= 70.56 USD (For Private Instance)
5*0.0196*24*30= 70.56 USD (For public Instance) or
1*0.0196*24*30= 14.112 USD (for public instance) or
1*0.0196*24*30= 14.112 USD (for private instance)

D. Cost on yearly Basis

2*0.0196*24*365= 343.392 USD(For 2 Instances) Elastic IP (Based on how much you use) If additional users join our server, there will be a lot of pressure for auto scaling, and the cost would be: 5*0.0196*24*365= 858.48 USD(For Private Instance)
5*0.0196*24*365= 858.48 USD (for public instance) or
1*0.0196*24*365= 171.696 USD(for public instance) or
1*0.0196*24*365= 171.696 USD(for private instance)

Analysis: The cost calculations offered provide a thorough overview of costs related to your server infrastructure over various time periods, offering useful information for financial planning and budgeting. On an hourly basis, it's evident that the cost for two instances is minimal at 0.0392 USD, with potential elasticity costs for additional users. This cost escalates when considering a 15-day cycle or a monthly basis, where the potential for auto-scaling due to increased user load becomes more significant, resulting in expenses of $14.112 and 28.224$, respectively, for two instances over a month. For yearly projections, the cost grows substantially to USD 343.392 for two instances. Elastic IP prices vary depending on the quantity of instances and how they are used. The prices can be significant for both private and public instances, with private instances costing as much as USD 858.48 per year. These estimates demonstrate the significance of planning your server infrastructure while taking both short-term and long-term expenditures into account. Costs associated with elasticity and auto-scaling can be very significant, especially in light of rising customer demand. To reduce costs and maintain performance and availability while optimizing costs, it's critical to monitor and modify your infrastructure. Additionally, researching cost-cutting measures like reserved instances or effective resource use might aid in minimizing costs.

VI. Conclusion and Future Plan

A. Conclusion

In conclusion, this research paper has delved into the critical issue of air quality management, highlighting the urgency of addressing the deteriorating air quality worldwide. The detrimental impact of poor air quality on human health, the environment, and the economy cannot be overstated. Throughout this study, we have explored various aspects of air quality management, including the sources of air pollutants, the effects of different pollutants, and the strategies and technologies used for mitigation.

We have found that effective air quality management requires a multi-pronged approach involving government regulations, technological advancements, public awareness, and international cooperation. The success stories presented in this paper, such as the improvement in air quality in cities like Beijing and Los Angeles, demonstrate that it is possible to achieve significant improvements with dedicated efforts.

B. Future Plan

Looking ahead, it is evident that air quality management will continue to be a pressing concern. To build on the progress made so far and ensure cleaner air for future generations, the following strategies and areas of focus are recommended:

1. Stricter Regulatory Frameworks: Governments and regulatory bodies should continue to strengthen and enforce air quality standards. Regular monitoring and stringent penalties for non-compliance should be implemented to hold industries and individuals accountable.

2. Clean Energy Transition: Accelerating the transition to clean and renewable energy sources, such as solar, wind, and electric vehicles, is vital for reducing emissions from fossil fuels. Governments should incentivize the adoption of these technologies and invest in clean energy infrastructure.

3. Public Awareness and Education: Initiatives to educate the public about the health risks associated with poor air quality and ways to reduce personal contributions to air pollution should be expanded. Citizen engagement can drive positive change.

4. Technological Advancements: Research and development efforts should be directed towards the creation of more efficient and cost-effective air quality monitoring and pollution control technologies. Innovation in areas like air filtration and emission reduction should be encouraged.

5. Global Collaboration: Air pollution knows no borders, and international cooperation is crucial. Countries should collaborate on sharing data, best practices, and strategies to combat transboundary air pollution effectively.

In conclusion, while significant progress has been made in air quality management, there is still much work to be done. By implementing stricter regulations, embracing clean energy, raising public awareness, fostering technological innovation, and fostering global cooperation, we can pave the way for a cleaner and healthier future for all.

VII. References

References

[1] MNM Aashiq, WTCC Kurera, MGSP Thilekaratne, AMA Saja, MRM Rouzin, Navod Neranjan, and Hayti Yassin. An iot-based handheld environmental and air quality monitoring station. *Acta IMEKO*, 12(3):1–9, 2023.

[2] Manzoor Ansari and Mansaf Alam. An intelligent iot-cloud-based air pollution forecasting model using univariate time-series analysis. *Arabian Journal for Science and Engineering*, pages 1–28, 2023.

[3] Patricia Arroyo, José Luis Herrero, José Ignacio Suárez, and Jesús Lozano. Wireless sensor network combined with cloud computing for air quality monitoring. *Sensors*, 19(3):691, 2019.

[4] Patrick C Campbell, Weifeng Jiang, Zachary Moon, Sonny Zinn, and Youhua Tang. Noaa's global forecast system data in the cloud for community air quality modeling. *Atmosphere*, 14(7):1110, 2023.

[5] Abderrahim El Mhouti, Asmae Bahbah, Mohamed Fahim, Yassine El Borji, and Adil Soufi. Improving weather forecasting using meteorological big data scraped from web sources: a cloud-based approach. *International Journal of Computing and Digital Systems*, 14(1):1–xx, 2023.

[6] Vasilis Evagelopoulos, Nikolaos D Charisiou, Milton Logothetis, Georgios Evagelopoulos, and Christopher Logothetis. Cloud-based decision support system for air quality management. *Climate*, 10(3):39, 2022.

[7] Giovanni B Fioccola, Raffaele Sommese, Imma Tufano, Roberto Canonico, and Giorgio Ventre. Polluino: An efficient cloud-based management of iot devices for air quality monitoring. In *2016 IEEE 2nd International Forum on Research and Technologies for Society and Industry Leveraging a better tomorrow (RTSI)*, pages 1–6. IEEE, 2016.

[8] Byron Guanochanga, Rolando Cachipuendo, Walter Fuertes, Santiago Salvador, Diego S Benítez, Theofilos Toulkeridis, Jenny Torres, César Villacís, Freddy Tapia, and Fausto Meneses. Real-time air pollution monitoring systems using wireless sensor networks connected in a cloud-computing, wrapped up web services. In *Proceedings of the Future Technologies Conference (FTC) 2018: Volume 1*, pages 171–184. Springer, 2019.

[9] Murat Karabatak, Twana Mustafa, and Chawan Hamaali. Remote monitoring real time air pollution-iot (cloud based). In *2020 8th International Symposium on Digital Forensics and Security (ISDFS)*, pages 1–6. IEEE, 2020.

[10] Somansh Kumar and Ashish Jasuja. Air quality monitoring system based on iot using raspberry pi. In *2017 International conference on computing, communication and automation (ICCCA)*, pages 1341–1346. IEEE, 2017.

[11] Kan Zheng, Shaohang Zhao, Zhe Yang, Xiong Xiong, and Wei Xiang. Design and implementation of lpwa-based air quality monitoring system. *IEEE Access*, 4:3238–3245, 2016.

[6] [1] [2] [3] [4] [5] [6] [7] [8] [9] [10] [11]