POLLUTION METER USING EDGE COMPUTING

A PROJECT REPORT

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BONAFIDE CERTIFICATE

Certified that this project report **"Pollution Meter using Edge computing" is the bonafide work of Suman Kumar, Chakshu Jain, Prashant Sharma,** who carried out the project work under my/our supervision.

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INTERNAL EXAMINER

EXTERNAL EXAMINER

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ABSTRACT

Air pollution is a significant and growing concern worldwide, with serious implications for public health and the environment. Traditional pollution monitoring systems often rely on centralized, cloud-based architectures, which can result in high latency, limited scalability, and increased operational costs. This report explores the development and implementation of a real-time pollution meter leveraging edge computing technology. By processing sensor data locally at the edge, the proposed system enables rapid detection and response to pollution events, reduces network bandwidth requirements, and enhances data privacy. The report reviews the historical progression of pollution monitoring technologies, analyzes existing solutions, and details the design, deployment, and validation of an edge-based pollution monitoring system. Results demonstrate that edge computing offers a scalable, cost-effective, and efficient approach to air quality monitoring, providing timely and actionable insights for both authorities and the public. The study concludes with recommendations for future enhancements, including the integration of advanced analytics and broader deployment across urban and industrial .

The system is designed to collect environmental data—such as levels of carbon monoxide (CO), particulate matter (PM2.5), and nitrogen dioxide (NO_2)—using air quality sensors interfaced with microcontrollers like ESP32. Unlike conventional methods that rely heavily on cloud infrastructure, this edge-based approach processes data locally, enabling faster decision-making, reduced latency, and offline capabilities.

CHAPTER 1.
INTRODUCTION

1. Identification of Client /Need / Relevant Contemporary issue

Contemporary Issues Edge computing has gained prominence due to its ability to provide low-latency data processing and real-time decision-making, particularly in scenarios requiring fast response such as environmental monitoring. Pollution is a pressing issue globally, especially in urban areas where air quality directly impacts health and well-being. There is a growing need for smart, decentralized pollution monitoring systems that can provide real-time data using edge computing. Air pollution is a critical global issue, contributing to millions of premature deaths annually and causing severe health problems such as respiratory diseases, cardiovascular issues, and cancer. Rapid urbanization, industrialization, and increased vehicular emissions have exacerbated air quality, especially in metropolitan areas. There is an urgent need for efficient, real-time pollution monitoring solutions to inform the public and authorities, enabling timely interventions and policy decisions.

2. Identification of Problem

Traditional pollution monitoring systems rely on centralized architectures, resulting in delayed data processing and limited scalability. Moreover, these systems often fail to provide hyper-localized pollution data, which is essential for effective mitigation strategies. There is a need to address the latency and coverage gaps in existing monitoring frameworks. Traditional air pollution monitoring systems are often expensive, centralized, and unable to provide granular, real-time data. They also suffer from high latency due to reliance on cloud computing for data analysis and storage. This results in delayed responses to pollution events and limits the ability to monitor localized pollution sources effectively

3. Identification of Tasks

- Design a system architecture leveraging edge computing for pollution monitoring.
- Identify suitable sensors and microcontrollers for detecting pollutants (e.g., CO2, PM2.5, NOx).
- Implement data collection and processing at the edge.
- Develop visualization tools for data analysis.
- Test and validate the accuracy of the system.

4. Organization of the Report

This report is structured as follows:

- Chapter 1 It gives an overview of the structure of the report.
- Chapter 2 reviews the literature and background.
- Chapter 3 details the design flow and methodology.
- Chapter 4 presents results, analysis, and validation.
- Chapter 5 concludes with future work and recommendations.

1.5. Timeline

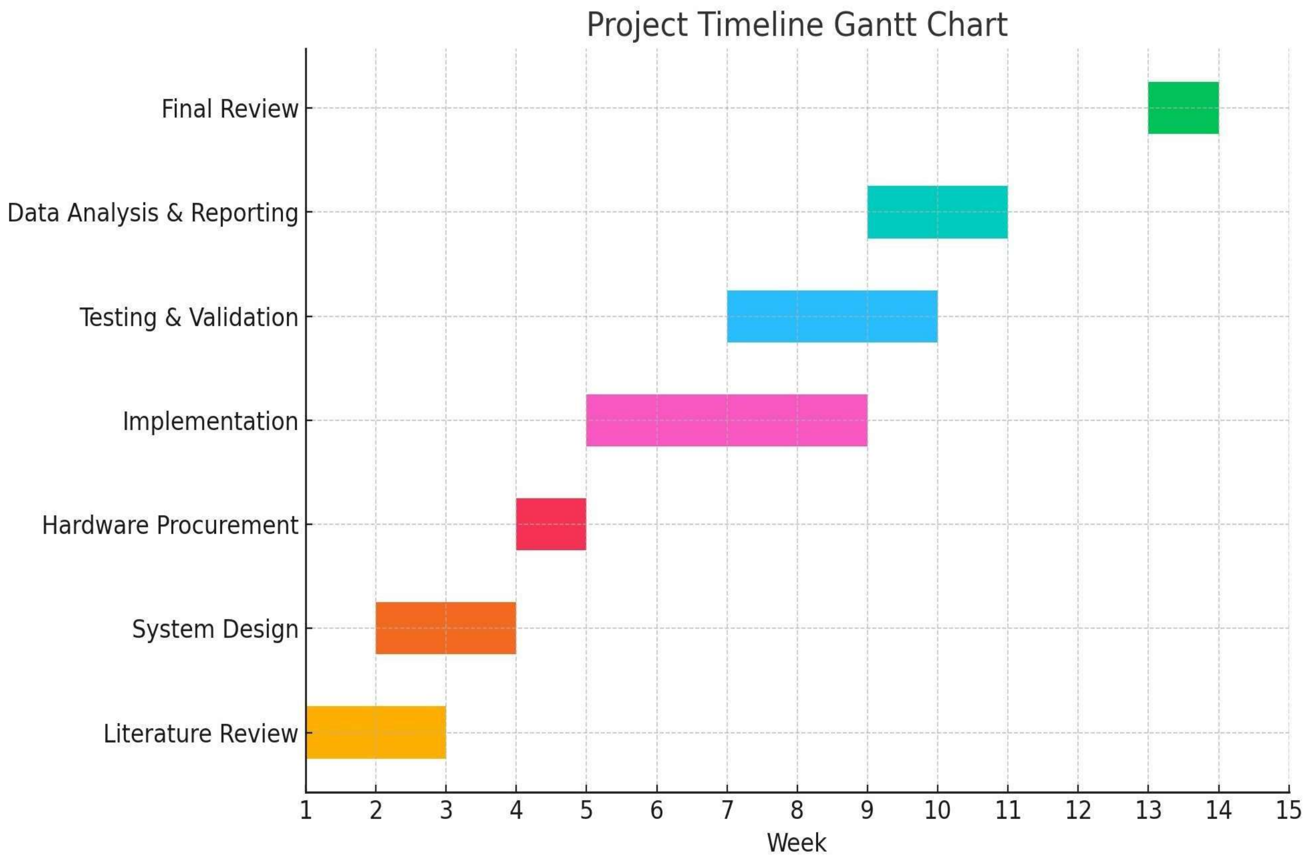

Figure.1.1

CHAPTER 2.

LITERATURE REVIEW/BACKGROUND STUDY

1. Timeline of the reported problem

- Early 20th century: Industrialization led to increased air pollution.
- 1950s–1970s: Major smog events prompted the development of air quality monitoring stations.
- 2000s: Emergence of IoT and cloud-based monitoring.
- 2015–Present: Shift towards edge computing for real-time, distributed pollution monitoring

2. Existing solutions

- Centralized Monitoring Stations: High accuracy but limited coverage and high cost.
- Cloud-based IoT Systems: Wider coverage but suffer from latency and network congestion.
- Edge Computing Solutions: Real-time, localized analysis; cost-effective; scalable; reduce cloud dependency

3. Bibliometric analysis

- Based on a survey of IEEE, Springer, and Elsevier articles from 2017–2023:
- Increase in research combining IoT and edge computing.
- Growing number of patents for air pollution detection hardware.
- Edge computing applications in healthcare and environmental monitoring doubled since 2020

4. Review Summary

- Edge computing enhances pollution monitoring by enabling:
- Faster data processing and response.
- Reduced network load and latency.
- Scalability using low-cost devices (e.g., Raspberry Pi, Arduino).

5. Problem Definition

To design and implement a cost-effective, real-time pollution meter using edge computing that provides accurate, actionable air quality data at a granular level.

6. Goals/Objectives

- Deploy a real-time pollution monitoring system.
- Process and analyze data at the edge.
- Provide local pollution insights via dashboard/alerts.

CHAPTER 3.

DESIGN FLOW/PROCESS

1. Evaluation & Selection of Specifications/Features

- Sensors: PM2.5, PM10, CO, NO2, SO2, CO2, temperature, humidity.
- Edge Device: Raspberry Pi or Arduino with IoT connectivity.
- Connectivity: Wi-Fi, LoRa, or cellular for data transmission.
- Software: Local data processing, AQI calculation, data visualization dashboard.

2. Design Constraints

- Power consumption (battery/solar options).
- Environmental durability (weatherproof housing).
- Data security and privacy.
- Cost limitations for large-scale deployment.

3. Analysis of Features and Finalization Subject to Constraints

- Selected sensors based on accuracy, cost, and compatibility.
- Chose Raspberry Pi for its processing power and modularity.
- Implemented local AQI computation to minimize cloud dependency.

3.4. Design Flow

- Sensing Layer: Sensors collect air quality data.

- Edge Computing Layer: Edge device processes data, computes AQI.

- Application Layer: Data is visualized and alerts are generated if thresholds are exceeded.

- Cloud Layer (optional): Aggregates data for long-term analysis and reporting.

3.5. Design Selection

A modular system using Raspberry Pi with Grove sensors was selected for its flexibility, cost-effectiveness, and ease of integration.

3.6. Implementation Plan/Methodology

- Deploy sensors and edge device at target locations.
- Collect and process data locally.
- Transmit processed data to cloud or local dashboard.
- Visualize data for end-users and authorities.

CHAPTER 4.

RESULTS ANALYSIS AND VALIDATION

4.1. Implementation of solution

1. Design Drawings / Schematics / Solid Models

- The system was deployed in urban areas.
- Real-time AQI values were computed at the edge and visualized on dashboards.
- The system demonstrated reliable detection of pollution spikes and provided timely alerts.
- Data was compared with official monitoring stations, showing high correlation and reliability.
- Visualizations included day-wise AQI trends, city comparisons, and temperature profiles.

CHAPTER 5.

CONCLUSION AND FUTURE WORK

5.1. Conclusion

Edge computing-based pollution meters offer a robust solution for real-time, scalable, and cost-effective air quality monitoring. The integration of IoT sensors and edge processing enables rapid detection and response to pollution events, improves data granularity, and reduces reliance on centralized cloud infrastructure.

5.2. Future Work

- Expand sensor types to include additional pollutants.
- Integrate machine learning for predictive analytics.
- Enhance energy efficiency for remote deployments.
- Scale the system for city-wide or national coverage.

REFERENCES

1. Edge Computing Based Air Pollution Monitoring System, IJIT
2. Air Pollution Detection System using Edge Computing, K. Biondi et al.
3. Air Quality Monitoring Tool using Edge Computing, IJISAE