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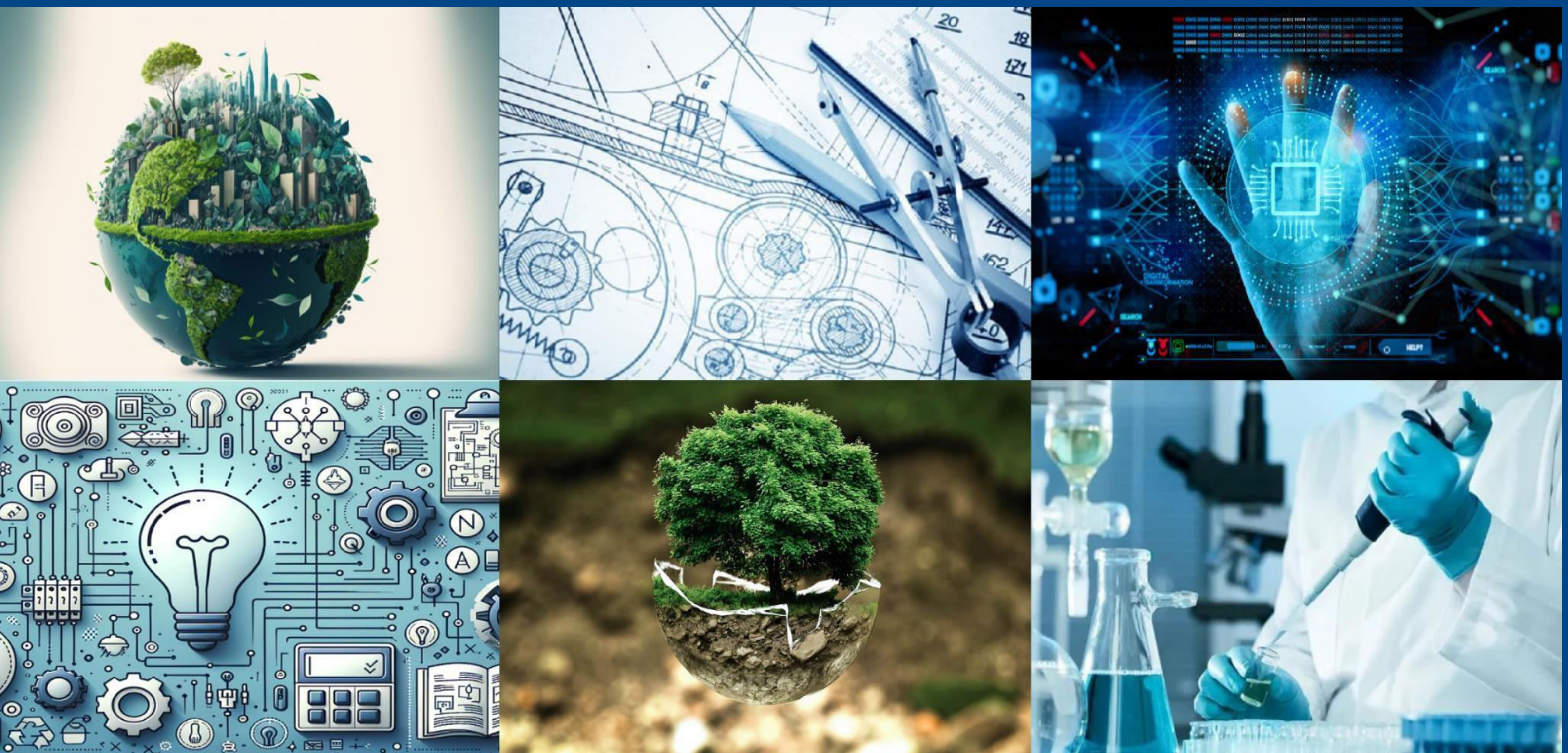

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Remote Air Quality Sensing and Temperature Monitoring System using IoT for Smart City Application

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ABSTRACT: The Remote Air Quality Sensing and Temperature Monitoring System using IoT for Smart City Application is designed to enhance urban environmental monitoring by leveraging IoT technology. The system is implemented in two phases, focusing on scalability and functionality. In the first phase, the system monitors ambient air temperature using a network of temperature sensors integrated with an IoT platform. Real-time data is collected, processed, and transmitted to a centralized system, enabling efficient monitoring and analysis through a mobile or web application. This phase provides insights into temperature variations, aiding in urban planning and management. In the second phase, air quality monitoring is integrated to assess environmental pollution. Sensors for parameters such as particulate matter (PM2.5 and PM10), carbon monoxide (CO), and nitrogen dioxide (NO2) are added to the system. The data collected is analyzed to provide actionable insights for improving air quality. Alerts and notifications are generated for significant deviations from predefined environmental standards. This project aims to contribute to the development of smart cities by enabling data-driven decision-making to improve environmental sustainability, public health, and urban living conditions. The modular design ensures ease of integration and future scalability, making it adaptable for diverse urban environments.

KEYWORDS: Internet of Things, Smart City, Environmental Monitoring, Temperature Monitoring, and Sensor Network.

I. INTRODUCTION

Air pollution is a growing environmental concern, with vehicular emissions being one of the primary contributors to deteriorating air quality in urban areas [1]. As the number of vehicles on the road continues to rise, so does the level of pollutants release into the atmosphere [2]. This increase in emissions poses serious health risks and contributes to climate change. In response to these challenges, there is a pressing need for solutions that enable real-time monitoring and management of vehicle emissions. Urbanization and industrialization have led to significant environmental challenges, including rising temperatures and deteriorating air quality in cities. Effective monitoring of these parameters is critical for sustainable urban development and ensuring public health. The Internet of Things (IoT) provides a transformative approach by enabling real-time monitoring and data analysis through interconnected devices. This project, Remote Air Quality Sensing and Temperature Monitoring System using IoT for Smart City Applications, aims to address these challenges by providing a scalable and efficient environmental monitoring solution. The system is designed in two phases to ensure incremental development and functionality [3]. In the first phase, the focus is on monitoring the ambient air temperature using IoT-enabled temperature sensors. This phase establishes the foundation of the system, offering insights into temperature variations across urban areas. Real-time data is displayed on an IoT platform, making it accessible for city administrators and citizens.

In the second phase, the system is enhanced to monitor air quality parameters, including pollutants like particulate matter (PM2.5, PM10), carbon monoxide (CO), and nitrogen dioxide (NO2). This integration enables comprehensive environmental monitoring, empowering authorities to take proactive measures against pollution and improving the quality of life in smart cities [4]. The modular and scalable design of this system ensures its adaptability to different urban environments. By providing accurate, real-time environmental data, the project contributes to informed decision-making for urban planning, environmental management, and public health initiatives.

II. LITERATURE SURVEY

Manjakkal et al., [5] presented the design and implementation of an autonomous water pollution monitoring system utilizing IoT-enabled surface vehicles. The system incorporates a network of unmanned boats equipped with a suite of sensors to measure various water quality parameters. Real-time data collection, processing, and transmission capabilities are achieved through onboard microcontrollers and wireless communication modules. Field tests conducted in different aquatic environments demonstrate the system's effectiveness in providing comprehensive and timely water quality information.

Sun et al., [6] explored the integration of machine learning techniques for predictive modeling of water quality in IoT-based monitoring systems. By leveraging historical sensor data and environmental variables, machine learning algorithms are trained to forecast future water quality conditions. The proposed approach demonstrates promising results in accurately predicting changes in key parameters such as dissolved oxygen, pH, and turbidity, thereby facilitating proactive management of water resources and pollution mitigation efforts.

Fascista et al., [7] presented a robust analysis of IoT-based water quality monitoring systems operating under adverse environmental conditions. Through extensive field tests and simulations, the study evaluates the performance of sensor nodes, communication networks, and data processing algorithms in challenging scenarios such as extreme weather events, biofouling, and sensor drift. The findings provide valuable insights for enhancing the resilience and reliability of IoT-enabled monitoring platforms in harsh aquatic environments.

III. PROPOSED METHODOLOGY

The methodology for the Phase 1 system, focused on air temperature monitoring, involves the integration of IoT technologies with environmental sensors to provide real-time data transmission and analysis. The process starts by selecting strategic locations for deploying temperature sensors across the city, ensuring representative coverage. Each sensor node is equipped with a high-accuracy temperature sensor (e.g., DHT11 or LM35), a microcontroller (NodeMCU or Arduino), and a communication module (Wi-Fi or LoRa) for wireless data transmission. In Phase 1, the primary objective is to measure temperature fluctuations over time. The sensors continuously capture temperature data, which is then processed by the microcontroller. This data is converted into digital packets and transmitted wirelessly to a cloud-based platform for storage and analysis. Data validation algorithms are applied at this stage to ensure the accuracy and reliability of the collected data. The cloud platform acts as the central hub, where data from all deployed sensor nodes is aggregated. Advanced analytics are applied to this data, allowing users to monitor temperature trends and detect unusual fluctuations. A user-friendly web or mobile application presents the data in real-time, displaying temperature readings, historical trends, and alerts for deviations from predefined thresholds. By using IoT technology, the system provides continuous temperature monitoring, creating a foundation for further enhancements in air quality monitoring. The modular structure of the system allows future phases to incorporate additional environmental sensors for broader monitoring capabilities. Figure 1 shows block diagram of IoT-enabled temperature monitoring and control system.

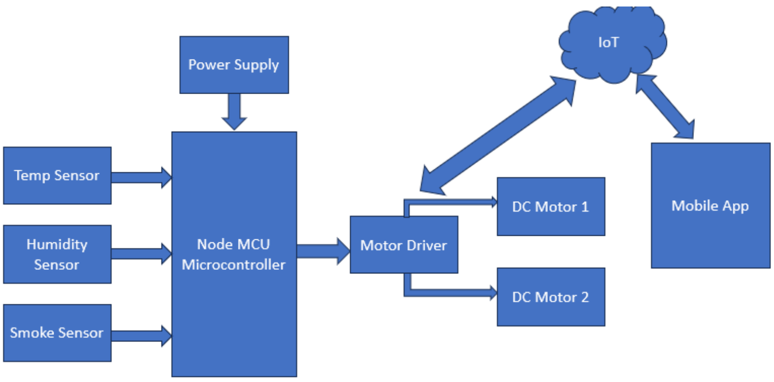

Figure 1: Block Diagram of IoT-Enabled Temperature Monitoring and Control System

The system works by deploying sensor nodes at key locations to monitor air temperature continuously. Each sensor node consists of a temperature sensor, microcontroller, and communication module. The temperature sensor measures the ambient temperature, generating analog signals proportional to the temperature value. The microcontroller (NodeMCU or Arduino) converts these analog signals into digital format and processes them to generate a data packet that includes the temperature reading, timestamp, and location information. The microcontroller then transmits this processed data wirelessly to a cloud-based platform via a communication module (Wi-Fi or LoRa). Once the data reaches the cloud, it is stored and processed to ensure data integrity and accuracy. Validation algorithms check for outliers, and only reliable data is stored for further analysis.

On the cloud platform, advanced analytics process the temperature data, identifying trends and detecting anomalies. A web-based or mobile application allows users to access this data in real-time. Visualizations such as graphs and charts make it easy to understand the temperature changes, and alerts are automatically generated when temperature readings deviate beyond predefined limits, notifying relevant authorities or users. This real-time monitoring system provides valuable insights into urban temperature dynamics, offering data-driven solutions to help manage climate control and environmental sustainability. As the system runs continuously, it ensures uninterrupted monitoring, allowing users to access the data at any time.

3.1 phase 2 proposed system

The proposed system follows a structured methodology to monitor air temperature and air quality parameters in urban environments. The system is implemented in two phases to ensure seamless functionality and scalability. Phase 1 involves deploying temperature sensors integrated with IoT platforms to collect and analyze temperature data. Phase 2 enhances the system by adding air quality monitoring capabilities using advanced sensors for particulate matter (PM2.5 and PM10), carbon monoxide (CO), nitrogen dioxide ($NO2$), and other pollutants.

The methodology begins with identifying key urban locations for deploying sensor nodes. These nodes comprise components like microcontrollers (e.g., NodeMCU or Arduino), sensors, communication modules (Wi-Fi, LoRa), and power sources (solar panels or batteries). Sensors collect environmental data, and microcontrollers process it into digital packets for wireless transmission to the cloud platform.

In the cloud, data is aggregated, validated, and analyzed using advanced algorithms to identify patterns, trends, and anomalies. Machine learning techniques enhance data accuracy, predict environmental changes, and provide actionable insights. A mobile and web-based dashboard is developed to display real-time data, graphical trends, and alerts for unsafe conditions.

Regular calibration of sensors and validation of data ensure reliability and accuracy. The modular design allows easy scaling of the system by adding new nodes or expanding functionalities. Alerts and notifications for hazardous levels are generated automatically and sent to concerned authorities and users, enabling timely action. This methodology ensures an efficient, robust, and scalable system to address urban environmental monitoring challenges, providing comprehensive insights for decision-making. Figure 2 shows block diagram of IoT-based temperature monitoring system with lcd display.

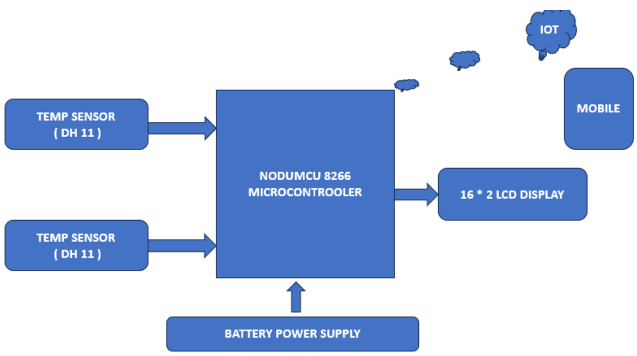

Figure 2: Block Diagram of IoT-Based Temperature Monitoring System with LCD Display

Pollution Sensor (e.g., MQ-135):
The pollution sensor, typically an MQ-135, is responsible for detecting air pollutants such as carbon monoxide (CO), nitrogen dioxide (NO2), ammonia, benzene, and other harmful gases. Positioned near the exhaust, the sensor continuously samples air quality, measuring the concentration of pollutants being emitted by the vehicle.

NodeMCU Microcontroller:
The NodeMCU microcontroller serves as the core of the system, processing input data from the pollution sensor and controlling other components. This microcontroller, powered by the ESP8266, has built-in Wi-Fi capabilities that facilitate IoT integration, allowing it to communicate with the Blynk platform seamlessly.

Buzzer:
The buzzer is connected to the NodeMCU and acts as an immediate alert mechanism within the vehicle. When pollutant levels exceed the acceptable threshold, the NodeMCU sends a signal to activate the buzzer, emitting a loud sound to alert the driver. This instant feedback within the vehicle informs the driver that emission levels are unsafe, prompting them to take corrective action, such as checking the exhaust system or scheduling a maintenance appointment.

Wi-Fi Module (Built-in on NodeMCU):
The NodeMCU's built-in Wi-Fi module, based on the ESP8266 chip, facilitates seamless data communication between the microcontroller and the cloud-based Blynk platform. This module allows the NodeMCU to connect to a Wi-Fi network, enabling it to transmit pollution data from the sensor to the Blynk server in real time.

Blynk Cloud Server:
The Blynk Cloud Server acts as a data bridge between the NodeMCU and the user's mobile device, allowing for real-time storage, processing, and visualization of pollution data. Once the NodeMCU transmits pollution readings to the Blynk server, the data is stored and processed, enabling the user to access both current and historical emissions data.

IV. RESULT AND DISCUSSION

The system successfully collected and transmitted real-time temperature and air quality data, including parameters like PM2.5, PM10, CO, and NO2, to a centralized cloud platform. Data updates occur at regular intervals, ensuring timely information availability for analysis. The sensors provided accurate measurements, validated through calibration and testing under various environmental conditions. The data validation algorithms effectively filtered out noise and outliers, ensuring high-quality data for analysis. The user-friendly mobile and web applications displayed real-time data and historical trends in graphical formats. Alerts and notifications for unsafe pollution levels were generated and delivered to users and authorities, facilitating proactive actions.

Figure 3: Temperature Monitoring

This figure 3 shows a temperature monitoring dashboard for Los Angeles, CA. It displays the current temperature as 23.8°C. A line graph illustrates temperature trends over a 24-hour period. The device status indicates that it is online. Alerts notify users of high-temperature events at specific times during the day.

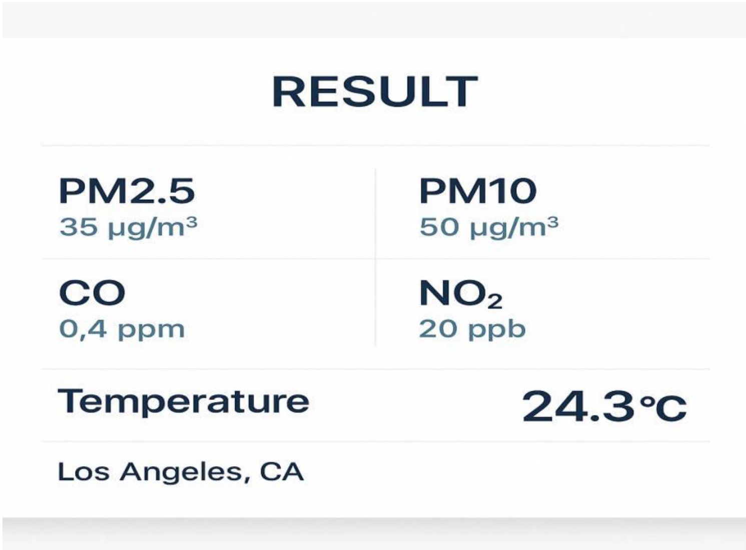

Figure 4: Air quality and temperature

This Figure 4 displays air quality and temperature results for Los Angeles, CA. The PM2.5 level is 35 µg/m³, and PM10 is 50 µg/m³, indicating particulate matter concentrations. The carbon dioxide (CO) level is 0.4 ppm, and nitrogen dioxide (NO_2) is 20 ppb. The current temperature is 24.3°C. These results help assess the environmental air quality in the area.

V. CONCLUSION

The IoT-based Remote Air Quality Sensing and Temperature Monitoring System offers a robust and scalable solution for addressing the environmental monitoring needs of smart cities. By leveraging IoT, advanced sensors, and cloud computing, the system successfully captures real-time data on air temperature and quality parameters, enabling proactive measures to enhance urban living standards. The project demonstrates the potential of integrating IoT technologies for environmental sustainability, with Phase 1 establishing a strong foundation through temperature monitoring and Phase 2 adding critical air quality tracking. The real-time alerts, visualizations, and historical data analysis provided by the system empower both authorities and citizens to make informed decisions. Scalability and modularity ensure the system's adaptability for larger urban areas or the inclusion of additional parameters in the future. Furthermore, the system fosters community awareness and engagement by making environmental data accessible to the public. In conclusion, the system exemplifies how technology can drive urban sustainability, improve public health, and facilitate efficient city management. It serves as a vital step toward achieving smarter, more sustainable cities, providing a model for similar implementations worldwide.

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