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# Survey Paper on Smart Home: Unified Environmental Safety System

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***Abstract: This presents a Gas Leakage and Air pollution Detection System using IoT technology, integrated with TinyML and a React Native mobile application. It is enhanced by an AI-powered chatbot to monitor gas leaks and air quality in real-time. The system is designed for domestic and industrial use, employing MQ2 and MQ135 sensors to detect gases such as LPG, methane, and pollutants. By integrating these sensors with equipment monitoring, the system promptly identifies leaks and reduces risks from hazardous emissions. Data is transmitted through a NodeMCU microcontroller to an IoTplatform for continuous tracking and analysis. Users receive instant mobile alerts when dangerous levels are detected, promoting safety. The application includes auser-friendly safety while raising environmental awarenessand safeguarding public health.***
***Keywords: IoT, TinyML, AI-powered, Edge computing, React Native, Gas detection, Air pollution monitoring, MQ2, MQ135, NodeMCU, ESP8266.***

## I. INTRODUCTION

The integration of Internet of Things (IoT), Artificial Intelligence (AI), and Tiny Machine Learning (TinyML) istransforming real-time monitoring systems, particularly indetecting gas leaks and air pollution. IoT sensors like MQ2and MQ135 continuously monitor hazardous gas levels and air quality in various environments, ensuring proactive detection. AI-powered chatbots within mobile applicationsprovide real-time alerts, safety advice, and interaction,making the system user-friendly and responsive. By leveraging IoT, sensors can be deployed across various environments to continuously monitor gas concentrations and air quality. The convergence of cutting-edge technologies is revolutionizing the way we monitor and respond to environment hazards.

Gas leaks and air pollution, which can pose severe risks to both human health and the environment, require real-time, proactive solutions that can operate efficiently with minimal power consumption. Harmful gases like LPG, methane, and other pollutants are prevalent in industrial and domestic settings, andundetected leaks can lead to devastating explosions or longtermrespiratory illnesses. Traditional gas detection systems often face challenges such as high -power consumption, latency in cloud-based data processing, and the need for continuous internet connectivity. This drastically reduces latency and power consumption, making it ideal for continuous monitoring in environments with constrained resources. IoT plays a crucial role by connecting sensors that detect hazardous gas levels andair quality metrices to a broader network. This combination provides a robust, energy-efficient solution for safeguarding health and improving air quality monitoring.

## II. METHODOLOGY

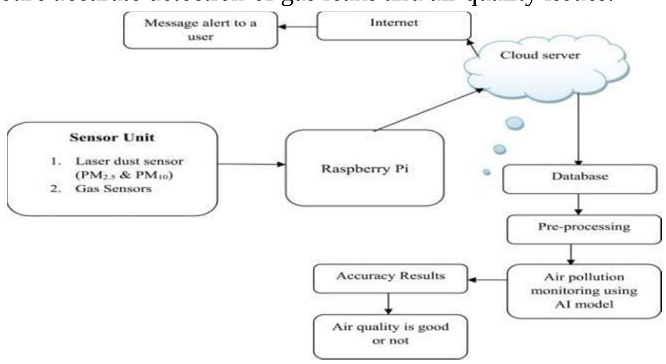
The methodology for developing the gas leakage and air pollution detection system combines IoT, Artificial intelligence (AI) and TinyML technologies to ensure realtimemonitoring and user engagement. The first methodology is sensor deployment, where the system employs MQ2 and MQ135 sensors to continuously monitor hazardous gases. Such as LPG, methane, and various air pollutants. These sensors are connected to a NodeMCU microcontroller, which serves as the central processing unit for collecting and managing data.

The second phase involves local data processing with TinyMLmodels implemented on the NodeMCU allowing for efficient analysis without relying on cloud services. This approach minimizes latency and reduces energy consumption, enablingimmediate detection of dangerous gas levels and improving the system's responsiveness. The reliance on cloud-based services for real-time analysis and enabling quicker responses to gas leak detections. Making the system more sustainable and suitable for long-term deployment in various environments.

IoT communication is the method by which the NodeMCU transmits processed data to an IoT platform via Wi-Fi, ensuring continuous monitoring and analysis of environmental conditions. This system architecture enables timely notifications and data access for users. The NodeMCU is an open-source IoT platform based on the ESP8266 wi-fi module.It is widely used for developing

IoT applications due to its affordability, versatility, and built-in Wi-Fi capabilities. It can be programmed using the Arduino IDE. This eliminates the additional Wi-Fi capabilities. Its simplifying the design and reducing costs for IoT applications that require internet connectivity.

The gas leakage in equipment and air pollution detection system includes a user-friendly mobile application developing with React Native, featuring an AI-powered chatbot that uses (NLP) to provide real-time alerts and safety information about gas levels and air quality. Users can customize alert thresholds to receive push notifications for potential hazards. Rigorous testing and calibration of the sensors and TinyML models ensure accurate detection of gas leaks and air quality issues.




## III. COMPARISON

The papers related to gas leakage and air pollution detection systems, such as the technologies used (sensors, microcontrollers, communication protocols), system architecture (IoT platforms, mobile integration), and realworld applications. it offers a balanced approach for gas and air quality detection. It provides a broader range of gases but may be more complex and expensive to implement. Uses NodeMCU (ESP8266) for IoT integration, transmitting data via HTTP and MQTT protocols. The simplicity and cost- effectiveness of NodeMCU make it widely adopted in many DIY IoT projects. Implements a more powerful microcontroller like Raspberry Pi or ESP32, enabling more sophisticated data processing and analytics. It also LoRa for ling-range wireless communication in industrial settings.

Data is uploaded to platforms like ThingSpeak or firebase, which are easy to use and offer reliable storage and visualization of real-time data. Uses AWS IoT or Microsoft Azure IoT, which provide more extensive cloud infrastructure, scalability, and advanced data analytics ThingSpeak and Firebase are lightweight, perfect for smaller projects and home environments. AWS IoT and Azure IoT are more suitable for large-scale industrial applications, with better security and more robust. Developed using React Native allowing the app to be crossplatform (Ios and Android), allowing for faster performance and tighter integration with hardware features such as location services or Bluetooth. Additional its corporates advanced features like machine learning to predict future air quality based on historical data. React Native offers flexibility and lower development time, native apps can be more efficient in terms of performance and integration with hardware. Extensively tested in industrial settings, such as chemical plants and factories. The paper includes results from field tests over several months, demonstrating the system's robustness in harsh conditions, including extreme temperatures and high humidity. Uses basic data visualization tools provided by ThingSpeak or firebase, showing trends over time through line graphs and bar charts.

## IV. CHALLENGES AND LIMITATION

Air Quality monitoring systems, while innovative, face several challenges and limitations. A key issue is maintaining accurate data transmission in areas with unreliable network connectivity. Though systems store data locally during outages, ensuring data integrity and minimizing delays when reconnecting remain complex. Sensor accuracy is another challenge, especially with lowcost sensors, which can suffer from drift over time and interference from environmental factors like temperature and humidity. Metal oxide sensors, often used for detecting gases such as VOCs and $CO_2$, are prone to cross-sensitivity, where they respond to multiple gases, making precise measurements difficult. Long-term calibration and addressing sensor degradation require significant resources, particularly in large-scale deployments.[2]

While integrating TinyML improves real-time analytics and reduces power consumption, it also introduces complexities in optimizing machine learning models for different environments and gas mixtures. The accuracy of these models may be constrained by limited high-quality training data and the computational limits of low-power edge devices.

Furthermore, scalability poses logistical challenges,particularly in large networks like smart homes or urban settings, where uniform deployment, data management, and standardization of sensor outputs across various models are difficult to ensure.

These limitations underscore the need for advancements in sensor technology, data processing algorithms, and overall system robustness to fully harness the potential of widespreadair quality monitoring systems.[4]

## V. WORKING

The Gas leakage and Air pollution Detection system operates through a coordinated interaction between its key components: gas sensors, a microcontroller, an IoT Platform, and a mobile application. Utilizing MQ2 and MQ135 gas sensors, the system is sensitive to various gases, including LPG, methane, and carbon monoxide. These sensors detect gas concentrations by measuring changes in electrical resistance when gas molecules interact with the sensor material, producing an analog voltage signal sent to the NodeMCU microcontroller for processing. The NodeMCU continuously reads these analog signals, converting them into digital format while applying calibration settings to ensure accuracy. Once processed, the data is transmitted to a cloudbased IoT platform, such as ThingSpeak or Firebase, using HTTP or MQTT protocols, allowing for real-time monitoring of gas concentrations and air quality levels. A mobile application developed with React Native retrieves the processed data from the IoT platform.[3]

Users can customize alert thresholds, if gas levels exceed these thresholds, the app triggers instant push notifications. This combination of real-time data processing and mobile alerts enhances safety, enabling prompt action in case of gas leaks or elevated pollutant levels, suitable for both domestic and industrial environments. Reliability is ensured through extensive testing in controlled settings and real-world applications, with sensors calibrated against known concentrations. The IoT platform also supports historical data storage, allowing users to visualize trends over time. The mobile app presents graphical representations of this data, helping users identify patterns, which can inform future safetymeasures and actions. Calibration settings are applied to the sensor data ensure accurate gas concentration readings.[4]

## VI. ADVANTAGES

The system offers several key advantages, particularly through its integration of low-cost sensors and IoT technology. One major benefit is real-time air quality monitoring, enabling immediate responses to environmental changes and potentially harmful conditions. The affordability of the sensors allows for broad deployment in various locations, both indoors and outdoors, ensuring comprehensive coverage. Even in situations where network connectivity is unreliable, the system stores data locally and transmits it when the connection is restored, ensuring no data is lost and maintaining a continuous record. The incorporation of machine learning, such as TinyML, significantly enhances the system's ability to classify gas mixtures and detect pollutants accurately, even in complex environments where crosssensitivity may typically cause issues. This makes the system more reliable and precise in detecting harmful pollutants. Additionally, users can easily access real-time data and historical trends through cloud-based storage and web interfaces, allowing for flexible and remote monitoring. The system's ability to provide both immediate alerts and long – term data analysis makes its a valuable tool for managing air quality in a wide range of environments. Its combination of cost – effectiveness, scalability, and advanced analytics makes it a practical and efficient solution for improving air quality management system [3],[4]

## VII. DISADVANTAGES

The system, while innovative, comes with several disadvantages that affect its overall performance and scalability. One of the primary issues is the reliability oflowcost sensors, which, though affordable, often suffer from accuracy problems such as sensors drift and sensitivity to environmental changes like temperature and humidity. These factors can lead to inconsistent data over time, requiring frequent recalibration to maintain precision, which can be both time-consuming and costly when deployed over large areas. Cross-sensitivity in sensors, particularly those detecting gases like VOCs and $CO_2$, is another challenge, as these sensors may respond to multiple gases, reducing the reliability of specific pollutant detection.

Furthermore, the dependence on network connectivity for real-time data transmission can lead to issues in areas with unstableinternet access. While the system stores data locally during network outages, this can cause delays in data processing andreporting, limiting the real-time monitoring capabilities that the system is designed to offer. TinyML's integration, although beneficial for low-power analytics, introduces complexity in terms of model optimization for diverse environments and gaseous mixture, and it may struggle with computational limitations of edge devices. Finally, scalability remains a challenge, particularly in large networks were maintaining uniform deployment, standardizing data outputs, and managing vast data sets becomes logistically difficult and resource – intensive.[2]

## VIII. FUTURE SCOPE

The future of air quality monitoring systems promises significant advancements driven by innovations in sensor technology, data analytics, and IoT integration. With ongoingresearch, these systems will become more reliable, scalable, and accessible for broader applications, including personal health, industrial safety, and urban planning. One of the key areas of focus will be improving sensors accuracy, durability, and the ability to withstand environmental fluctuations, reducing the need for frequent recalibration and maintenance. Additionally, leveraging advanced machine learning and AI technologies will allow for better predictive analysis and real- time monitoring. These improvements, combined with expanded use in smart cities, homes and global initiatives, will significantly enhance the ability to monitor and manage air quality effectively.

Enhanced sensor technologies: Future advancements will focus on improving sensor accuracy, longevity, and robustness against environmental factors like temperature and humidity. These improvements will reduce the frequency of recalibration and minimize issues like cross-sensitivity, making sensors more reliable for long-term monitoring and capable of delivering consistently precise air quality data.

1) Advanced machine learning integration: Future systems will incorporate more powerful machine learning algorithms to better analyze complex gas mixtures, improving pollutant detection accuracy and efficient real-time processing across diverse environmental conditions.
2) Automated calibration: Implementing automated calibration processes will streamline maintenance by reducing the need for manual adjustments. This enhancement will ensure consistent sensor accuracy, improve operational efficiency, and facilitate large-scale deployments byminimizing human intervention in sensor management.
3) IoT and smart city integration: Future air quality monitoring systems will seamlessly integrate with IoT frameworks in smart cities, enabling comprehensive environmental monitoring. This integration will enhance urban planning, facilitate data sharing among devices,facilitate data sharing among devices, and promote real-time responses to air quality issues for public health.
4) Health and wearable device integration: Integrating airquality monitoring with wearable health devices will allow users to track pollution effects on their health, providing realtime alerts and recommendations to minimize exposure toharmful pollutants.
5) Energy-efficient systems: Future air quality monitoring will prioritize low-power sensors and energy-harvesting solutions, reducing operational costs, extending battery life, and enabling sustainable large-scale deployments in remote environments.
6) Edge computing: Future air quality monitoring systems will leverage edge computing to process data locally, enhancing real-time capabilities, improving privacy, and reducing reliance on cloud storage, ensuring faster responses to changing air quality conditions.[3]

These advancements will transform air quality monitoring into a robust, integrated system capable of predictive analytics. By providing accurate, real-time data on pollutants, the system will enhance decision-making, faster community awareness, and support global initiatives aimed at improving public health and promoting environmental sustainability.

## IX. CONCLUSION

In conclusion, the evolution of air quality monitoring systems represents a significant advancement in our ability to assess and manage environmental health. The integration of low-cost sensors and IoT technologies has made it possible to deploy comprehensive monitoring networks across various settings, including urban, industrial, and indoor environments. These systems facilitate real-time data collection, enabling users to access vital information on air quality and make informed decisions to mitigate health risks associated with air pollution. As awareness of environmental issues grows, these monitoring systems will play a crucial role in empowering communities and stakeholders to take proactive measures in addressing air quality challenges.

The incorporation of advanced technologies, such as machinelearning and edge computing, further enhances theeffectiveness of air quality monitoring. Machine learning algorithms allow for more accurate pollutant detection and predictive analytics, while edge computing enables real-time data processing and analysis at the source. These innovations improve the responsiveness of monitoring systems and reducethe dependency on centralized data processing, thus enhancingprivacy and data security. By providing actionable insights, these systems contribute to better urban planning, policy formulation, and public health strategies.

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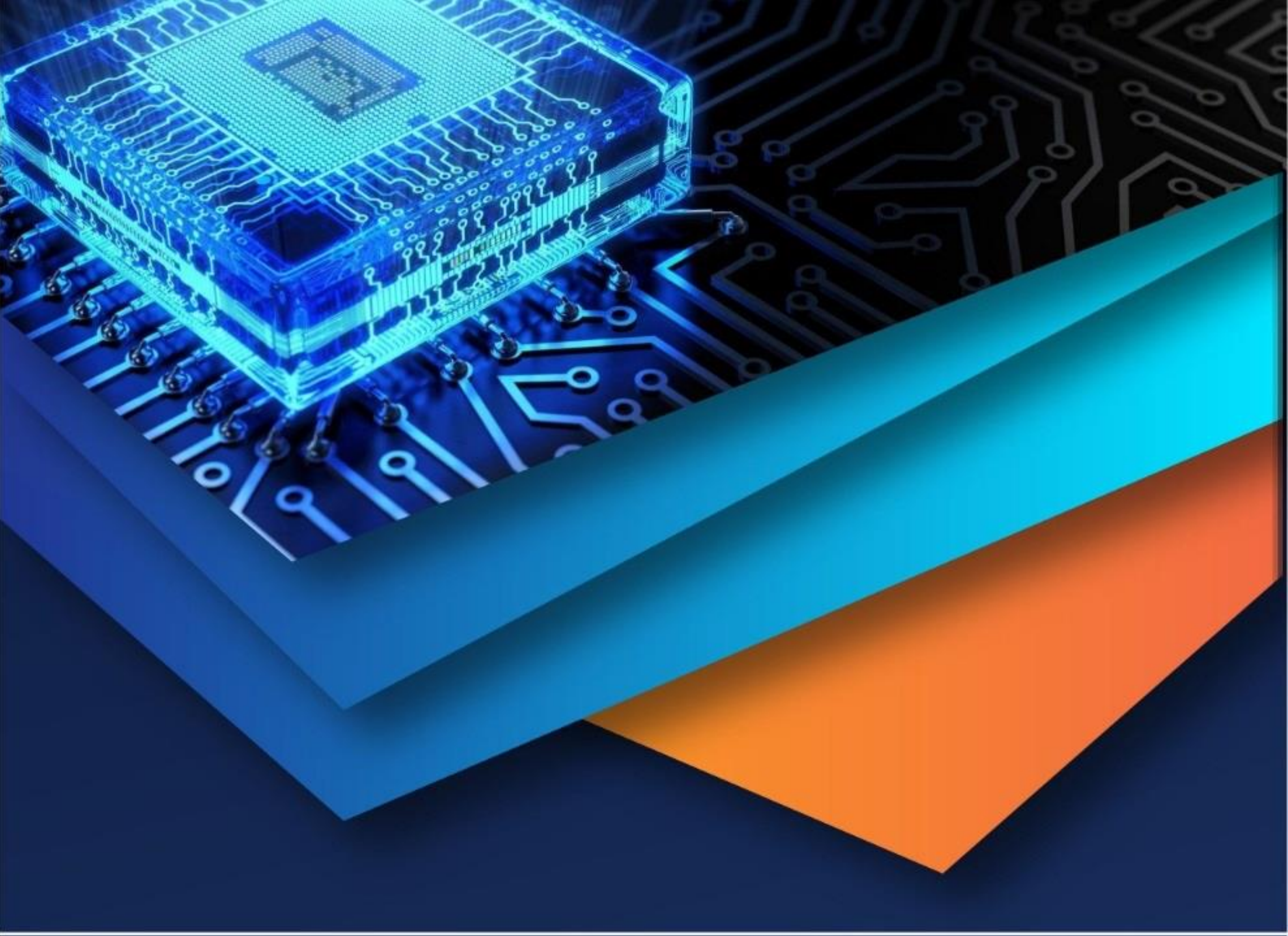


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