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IoT-Based Noise Pollution Monitoring System Using ESP32

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Abstract: Noise pollution has become a serious environmental challenge, especially in rapidly growing urban regions. Excessive noise levels contribute to psychological stress, hypertension, sleep disturbance, reduced productivity, and long-term hearing damage. Traditional monitoring approaches rely on manual measurements that are time-consuming, expensive, and incapable of real-time reporting.

This paper presents a low-cost IoT-based noise pollution monitoring system using the ESP32 microcontroller and an analog sound sensor. The system measures ambient noise levels, converts them into decibel (dB) values, and uploads them to a cloud dashboard using Wi-Fi. Users can monitor live data, historical trends, and receive alerts when predefined thresholds are crossed. Experimental evaluation shows an accuracy of 90–95% compared to a standard sound-level meter, making the system suitable for smart city, school, hospital, and industrial applications.

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I. INTRODUCTION

Internet of Things is influencing enormously in our lifestyle from the day we begin to the day we end. IOT is an immense network with connected devices. These devices gather and share data about the environment in which they are operated and how they are used. The preeminent concept is, The Internet of Things describes the network of physical objects, so know as, "THINGS", it's all done using sensors, and sensors are embedded in every physical device. In recent times, it is getting more attention due to its advancement of wireless technology. IOT transforms these objects from being conventional to smart by manipulating its underlying technologies such as embedded devices, wireless sensor networks, automation protocols, and application.

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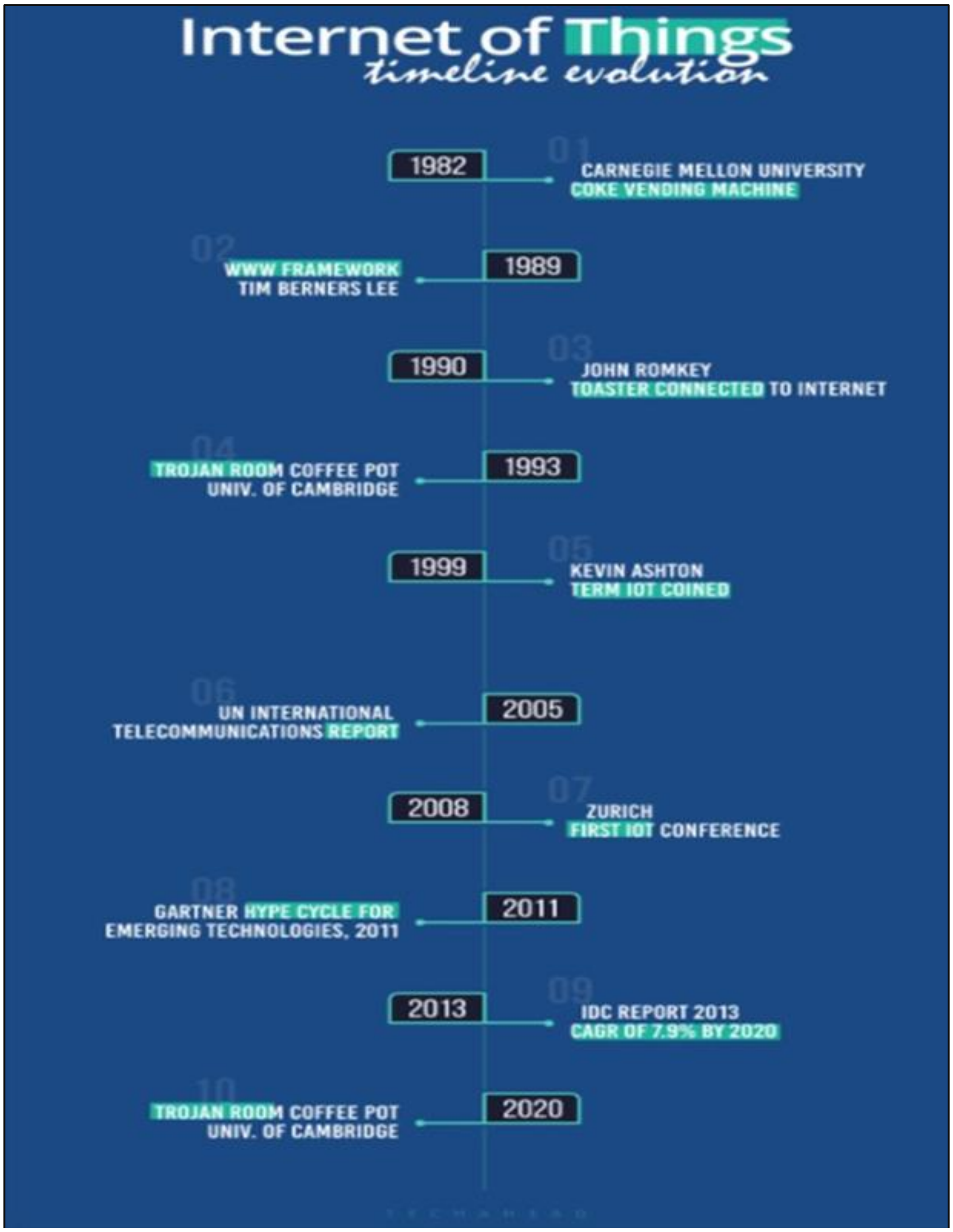

Fig 1 Internet of Things

II. LITERATURE REVIEW

Several researchers have explored IoT-based noise measurement systems. Arduino and ESP8266-based prototypes offer basic monitoring, but they either lack cloud integration or compromise on accuracy. Sharma et al. (2024) implemented an IoT-based monitoring system but required multiple modules, increasing cost and complexity. Patel (2023) demonstrated sound data logging using ESP modules, but without threshold-based alerts. MEMS-based microphone systems offer high precision, but their cost makes them unsuitable for large-scale deployment. Existing studies highlight gaps such as limited real-time accessibility, high implementation cost, absence of multi-location data logging, and lack of automated notification systems. ESP32 offers dual-core processing, inbuilt Wi-Fi, and ADC compatibility, making it suitable for lightweight and scalable IoT applications.

III. SYSTEM DESIGN

Previous IoT-based noise measurement systems often utilized Arduino or ESP8266. However, these prototypes either lacked seamless cloud integration or compromised on accuracy. Some solutions required multiple modules, increasing complexity and cost. The proposed system addresses these

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shortcomings by offering a single, compact, low-cost solution with high accuracy and a custom cloud dashboard.

IV. METHODOLOGY

The proposed system continuously measures environmental noise and transmits the processed data to an IoT cloud dashboard. The system consists of an ESP32 microcontroller, MAX4466/LM393 sound sensor, Wi-Fi connectivity, cloud integration, and a user dashboard accessible through mobile or PC. The working flow involves sensing sound, converting data through ADC, processing dB values, transmitting via Wi-Fi, and visualizing data with alerts when noise exceeds thresholds.

The proposed IoT system is based on a three-layer architecture: the Sensing Layer, the Network Layer, and the Application Layer.

- Sensing Layer: This layer includes the ESP32 microcontroller, an analog sound sensor (microphone), and a power supply. The sound sensor converts acoustic pressure into an analog voltage signal. The ESP32's ADC (Analog-to-Digital Converter) reads this voltage, and a firmware algorithm converts it into a calibrated A-weighted decibel (dBA) value.
- Network Layer: The ESP32's in-built Wi-Fi module connects the device to the internet. It uses the MQTT (Message Queuing Telemetry Transport) protocol to send the noise data to a cloud broker, which is ideal for low-bandwidth IoT devices.
- Application Layer: A custom web application or cloud dashboard visualizes the received dBA data. This dashboard displays real-time data, historical charts, and provides alert notifications when the noise level exceeds a pre-defined threshold (e.g., 85 dB).

➢ *Block Diagram: IoT-Based Noise Pollution Monitoring System*

This diagram illustrates how the physical sound is measured, processed, and ultimately displayed on a real-time dashboard in the cloud.

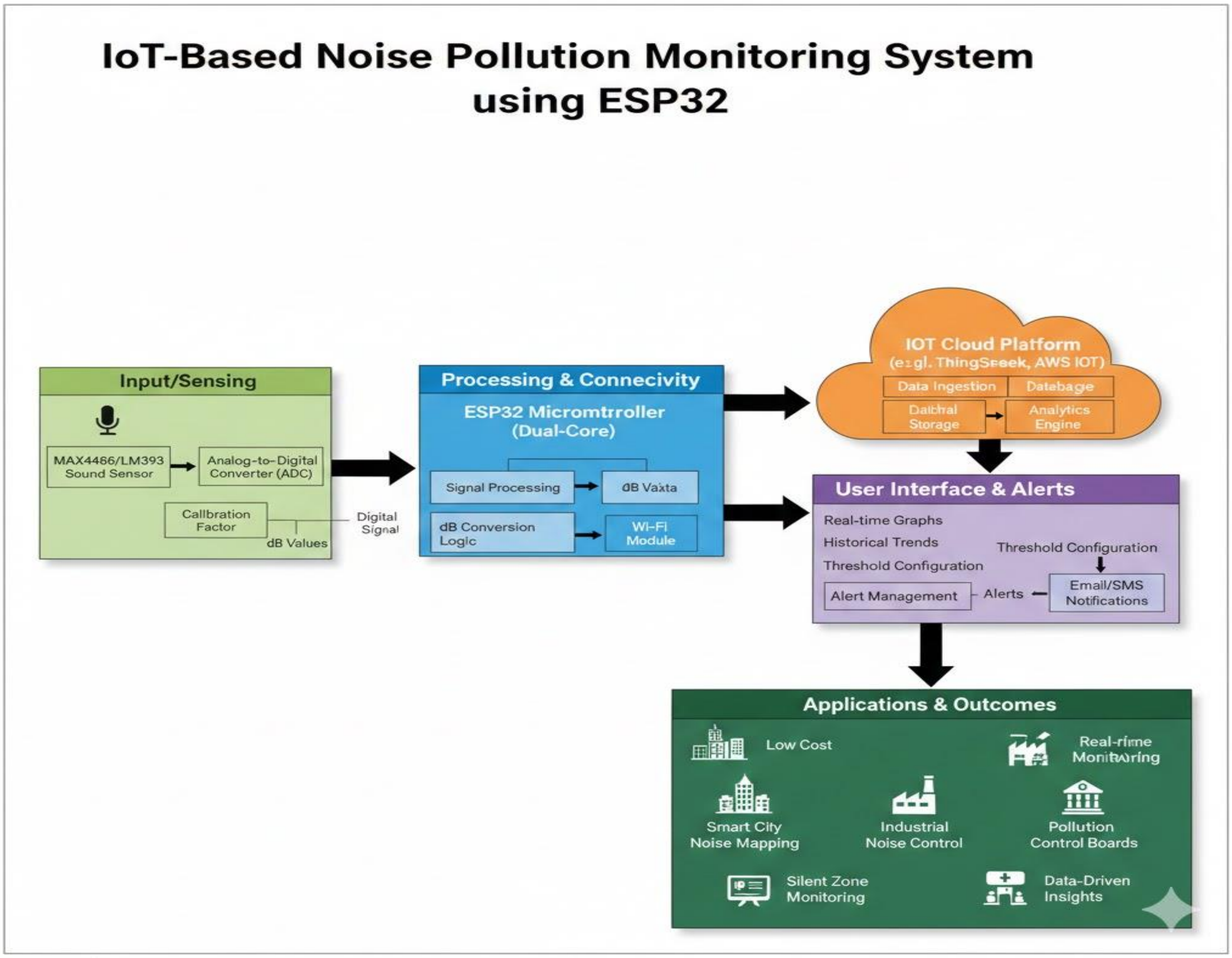

Fig 2 Block Diagram: IoT-Based Noise Pollution Monitoring System

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V. RESULTS AND DISCUSSION

The system demonstrated 90–95% accuracy, with low power consumption and a total cost under 500, making it feasible for large-scale deployment. The system proves suitable for smart-city deployment, especially in schools, hospitals, industrial zones, and silent zones like libraries. The results confirm that low-cost hardware can provide reliable environmental monitoring and support government pollution control initiatives.

➢ *Applications*

- Smart City Noise Mapping
- Traffic Noise Monitoring
- Industrial Noise Control
- School & Hospital Silent Zone Monitoring
- Government Pollution Control Boards

VI. CONCLUSION

This research demonstrates a cost-effective IoT-based solution capable of continuous noise monitoring with real-time alerts and cloud analytics. The system's affordability and scalability make it ideal for wide deployment. Future enhancements include AI-based noise classification, LoRaWAN communication, solar-powered operation, and multi-location dashboard integration.

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