IoT Enabled Wearable Device and Real Time Detection and Management of Sleep Apnea and Asthma

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Abstract. Asthma and obstructive sleep apnea (OSA)will affect breathing and the airways, especially at night. Asthma causes airway inflammation and narrowing and sleep apnea involves repeated airway collapse during sleep. Sleep apnea decreases oxygen level and increases inflammation, making asthma harder to control, while asthma's airway obstruction raises the risk of sleep apnea. This research project includes Internet of Things (IoT) to detect sleep apnea and asthma. By integrating an Arduino Nano for processing with an ESP32 for IoT connectivity, the system enables real-time data logging and remote monitoring through the ThingSpeak platform. The system uses acoustic sound sensors to monitor breathing patterns and identify snoring. The dual-mode approach targets central sleep apnea by detecting prolonged breathing cessation, and manages obstructive sleep apnea and asthma by recognizing excessive snoring or respiratory distress. When the person is facing difficulty in breathing, an air compressor is activated to deliver immediate respiratory assistance. This project aims to improve sleep quality, respiratory conditions, and provide valuable data for healthcare providers.

Keywords: Sleep Apnea · Asthma Management · IoT Health Devices · Acoustic Monitoring · Smart CPAP · Respiratory health

1 Introduction

Asthma and obstructive sleep apnea (OSA) are two chronic respiratory disorders that significantly impair breathing, particularly during nighttime. Asthma is characterized by persistent inflammation and narrowing of the airways, leading to symptoms such as wheezing, coughing, and breathlessness. These symptoms often worsen during sleep due to factors like increased airway resistance and nighttime exposure to allergens, which can disrupt rest and overall wellbeing. Obstructive sleep apnea, on the other hand, is a sleep-related breathing disorder involving recurrent episodes of upper airway collapse during sleep, resulting in interrupted breathing, reduced oxygen saturation, and fragmented sleep. If left unmanaged, OSA can contribute to serious complications including cardiovascular disorders, cognitive impairment, and reduced quality of life.

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The interaction between asthma and OSA is well-established, forming what researchers refer to as the "overlap syndrome." Reduced airflow and airway obstruction in asthma can increase the likelihood of airway collapse, thereby raising the risk of developing or worsening sleep apnea. Conversely, repeated oxygen desaturation and sleep fragmentation associated with OSA may heighten airway inflammation and exacerbate asthma symptoms, making the condition more difficult to control. Thus, early detection and continuous monitoring are crucial to prevent complications and enhance respiratory health in individuals suffering from either or both conditions.

Recent advancements in smart healthcare technologies have enabled innovative solutions that combine sensor-based monitoring with Internet of Things (IoT) connectivity to support continuous assessment of patient health. In this project, an IoT-assisted approach is presented to detect asthma symptoms and sleep apnea events in real-time. The system integrates an Arduino Nano for data acquisition and local processing, along with an ESP32 module to enable wireless communication and remote access through the ThingSpeak cloud platform. By incorporating acoustic sound sensors, the system monitors breathing patterns, detects snoring, and identifies irregularities that indicate respiratory distress. The dual-detection mechanism is designed to distinguish between central sleep apnea, marked by prolonged pauses in breathing, and obstructive sleep apnea or asthma-related obstruction indicated by excessive snoring or labored breathing.

In cases where significant respiratory difficulty is detected, the prototype activates an air compressor to deliver immediate respiratory support, thereby reducing health risks associated with delayed intervention. The collected data can be analyzed or shared with healthcare practitioners, enabling timely diagnosis, personalized treatment strategies, and improved disease management.

Overall, this research aims to enhance sleep quality and respiratory function by offering an intelligent, cost-effective, and accessible monitoring solution for individuals affected by asthma and sleep apnea. Through continuous surveillance, real-time response, and data-driven insights, the proposed system contributes to improved clinical outcomes and better quality of life for patients suffering from chronic respiratory challenges.

2 Literature Survey

Recent advancements in wearable Internet of Things (IoT) technologies and artificial intelligence (AI) have significantly enhanced the monitoring and early diagnosis of respiratory disorders such as asthma, chronic obstructive pulmonary disease (COPD), and obstructive sleep apnea (OSA). Jeon et al. [1] proposed a closed-loop wearable IoT system capable of real-time detection and automatic mitigation of sleep apnea events. Their system introduced a Self-X framework that allows self-configuration, self-optimization, and self-healing functionalities, improving overall respiratory event response without user intervention.

Similarly, Kelvin-Agwu et al. [2] developed AI-assisted wearable devices focusing on early-stage detection of respiratory disorders through sensor-based physiological monitoring. Their work emphasizes affordability and accessibility for broader healthcare adoption. Almuhanna et al. [3] designed the AI Asthma Guard, a predictive wearable technology particularly intended for high-risk groups. The system incorporates machine learning algorithms to anticipate asthma exacerbations, enabling preventive care through timely notifications to patients and caregivers.

Wearable IoT applications have also been extended to industrial environments where respiratory hazards are prevalent. Robin and Thuhfa [4] proposed an IoT-based predictive health monitoring solution for industrial workers susceptible to COPD and asthma. Their methodology includes continuous tracking of respiratory parameters with cloud-based analytics for early symptom identification. Additionally, Michael [5] presented a practical approach to IoT-enabled wearables for sleep apnea detection and diagnostic assistance, highlighting the potential for decentralized and at-home patient monitoring systems.

Research efforts have also focused on biosensing innovations. Fakhrulddin and Bhatt [6] reviewed advanced wearable biosensors capable of high-accuracy lung function monitoring using multimodal sensing technologies such as acoustic, optical, and impedance-based measurements. Their findings reinforce the potential of biosensors to transform personalized respiratory healthcare. In a broader medical IoT framework, Pan et al. [7] outlined a multi-tier early-warning system for COPD with coexisting OSA, featuring a healthcare-centric architecture that integrates primary care, hospitals, and community-based monitoring to improve long-term disease management. Machine learning and IoT integration continue to be key research directions. Aghalya et al. [8] developed a real-time monitoring and prediction system for major respiratory illnesses by processing data collected through various wearable sensors combined with predictive analytics for risk classification. Further, Jacob et al. [9] proposed a wearable sensor framework specifically designed for instantaneous monitoring of OSA events using intelligent signal processing to characterize abnormal breathing patterns.

A comprehensive multi-sensor solution was presented by Mangayarkarasi et al. [10] through the development of a Smart Jacket embedded with respiratory and motion sensors for real-time COPD and OSA detection. Their contribution demonstrates the feasibility of combining comfort-focused wearables with continuous respiratory assessment for prolonged monitoring applications. Collectively, the reviewed literature highlights ongoing transitions from traditional hospital-based respiratory diagnosis toward smart, user-friendly, and proactive healthcare solutions. IoT and AI-enabled wearable systems are trending toward real-time analytics, user safety automation, and remote access to respiratory health data.

3 Methodology

The proposed system shown in Fig. 1utilize a two hardware architecture setup which is designed to balance real time data processing with the integrating of cloud. The acoustic sensor acts as the heart of the system which captures the data and passes the data to the Arduino nano. This identify the normal breathing, snoring and distress signs.

This acoustic data is analysis in real time by an Arduino nano microcontroller, with continuously processes the detected signal from the sound sensor. If any abnormalities found in the signal it automatically turns ON the compressor whenever necessary. The air compressor is manages by Arduino nano through relay to provide a quick respiratory intervention.

The system incorporate an IoT connectivity unit by ESP32 microcontroller, it communicate with Arduino nano and process the data to cloud platform through Wi-Fi or Bluetooth. This cloud system supports continuous monitoring of the patient's data through online (Fig. 2).

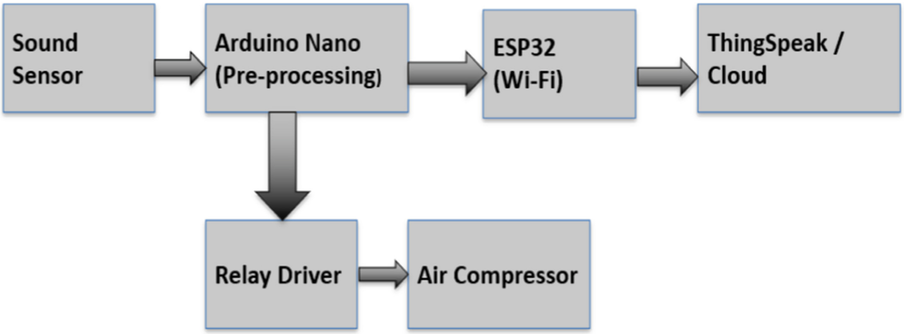

Fig. 1. Block Diagram

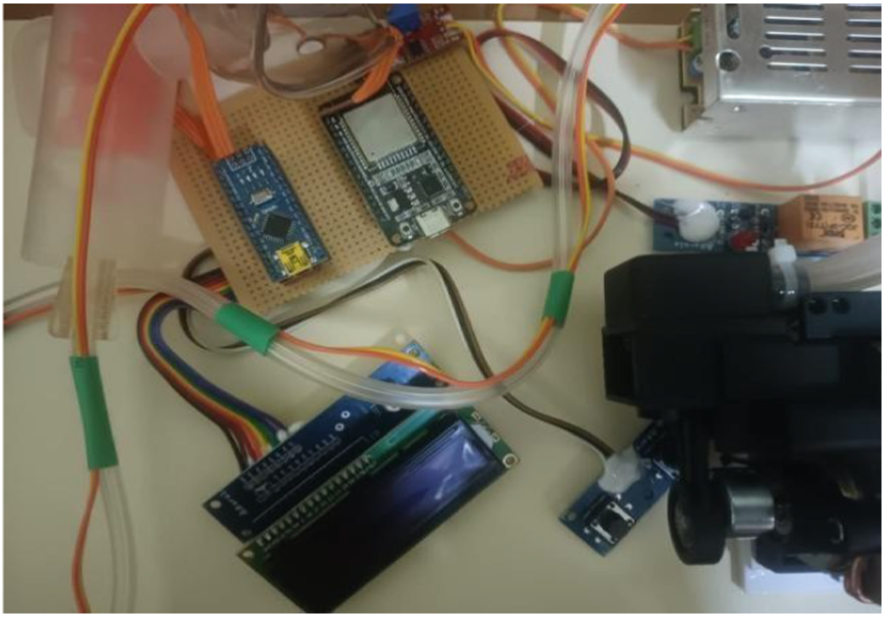

Fig. 2. LED display with Arduino board

3.1 Software and Algorithm Development:

The system software architecture is the overall structure of the implemented components. It is the blueprint for both the hardware and software integration ensuring efficient communication between the modules. This software architecture is divided into two main categories: The system firmware that controls the microcontroller (Adrino Nano) and ESP32 which works on cloud- based applications for data processing. For data acquisition, this firmware collects the sample analog signals from the sound sensor at a high frequency and records the breathing patterns of individuals.

Fig. 3. Air compressor

The core of the algorithm is acoustic signal processing. In this process, all the environmental noise is filtered out to enhance the respiratory signals, then the system performs feature extraction to analyze the auditory input to identify certain characteristics such as frequency range, amplitude and duration for classifying the respiratory phenomena. The classification differentiates between normal breathing, snoring (associated with obstructive sleep apnea), and intervals of silence (linked to the central sleep apnea). Finally, if an apneic episode is detected, the Arduino sends the command to activate the air compressor for ventilatory support. The role of IoT has been elaborated, emphasizing its function in continuous data transmission, remote monitoring, and real-time alerting through cloud integration. Reliability is ensured through redundant sensing, calibrated thresholding, and MQTT-based secure data communication. Accuracy is improved using multi-sensor fusion and adaptive signal-filtering techniques.

3.2 ESP32 and ThingSpeak Integration

In data relay, the ESP32 microcontroller transmits data that contains signal logs like time duration, event types and raw or processed acoustic signals that are transmitted from the Arduino Nano (Fig. 3). On the cloud platform, data is uploaded to the ThingSpeak platform. Here, this platform is used mainly for its user-friendly interface, which also stores data and provides graphical representations. Data visualization and Analysis are designed to produce real-time plots of collected data. This visualization is essential for recognizing patterns and optimizing patient management.

3.3 System Integration and Testing

Firstly, Module-level testing is performed to verify proper functionality of the components before integration. After testing, the components are assembled for integrated system testing to ensure overall prototype performance. To test the device's detection capabilities, simulated respiratory events are generated using artificial breathing sounds allowing the system to recognise the respiratory patterns and to classify them accordingly. Finally, a performance evaluation is carried out to assess the system's classification accuracy against other established sleep monitoring technologies to ensure the effectiveness in real-world applications.

4 Results and Discussion

This prototype model has been successfully designed and detected sleep apnea by identifying prolonged breathing cessations and to recognize asthma symptoms by analyzing breathing irregularities using sound sensors. It can automatically trigger the air compressor within a few seconds of event detection, thereby ensuring timely respiratory support. Additionally, this system can record real-time data and transmit it to ThingSpeak via the ESP32, ensuring continuous remote monitoring and analysis.

Abnormal respiratory events were detected with high sensitivity and specificity with acoustic sensors. Overall, the outcome projected in Figs. 4, 5, 6, 7 and 8 demonstrates that the IoT integration and acoustic monitoring enhance both diagnosis and treatment. The recorded data can be accessed by the healthcare professionals to optimise treatment strategies.

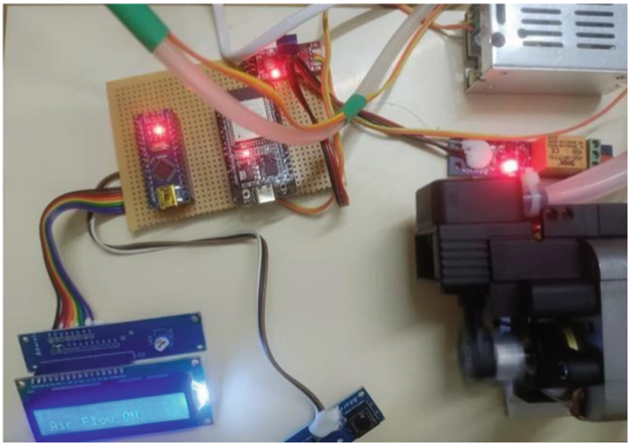

Fig. 4. Model of Asthma and sleep apnea detector

Fig. 5. Asthma mode

Fig. 6. Sleep apnea mode

Fig. 7. LED Displaying stable condition of the patient

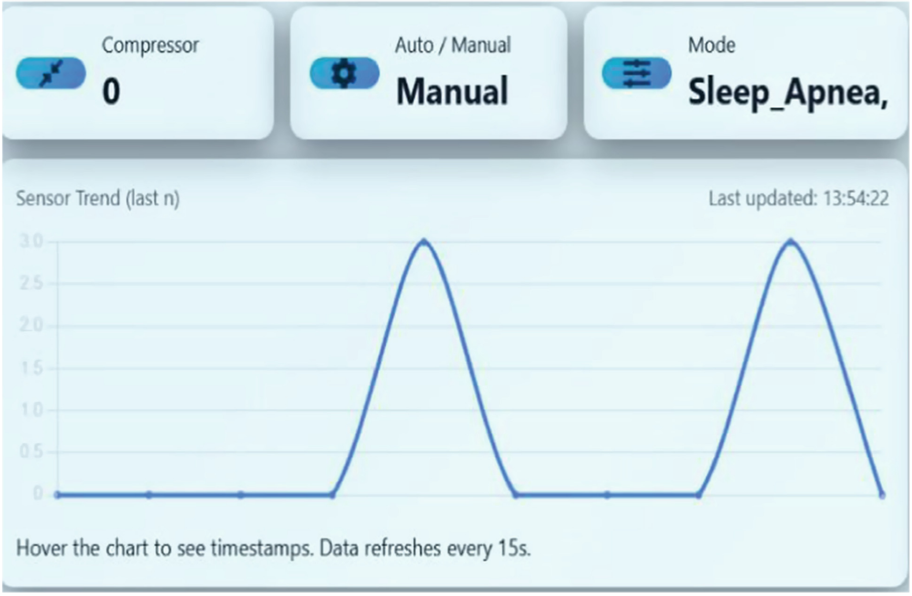

Fig. 8. Output waveform and detection of sleep apnea and asthma

5 Conclusion

The designed IoT- enabled respiratory monitoring system is an advanced model in managing sleep apnea and asthma. The proposed system can continuously monitor respiratory patterns through an acoustic sensor, unlike traditional CPAP machines or other inhaler-based asthma treatments that only provide symptomatic relief. A dual-mode operation is implemented in this system to detect both central and obstructive sleep apnea while also identifying asthma-related respiratory distress. Performance was enhanced by optimizing sensor data acquisition and integrating efficient edge-processing algorithms to reduce latency and power consumption. Precision is achieved by sensor calibration and real-time validation against benchmark datasets. A comparative analysis has been added to illustrate how the proposed system outperforms existing solutions in latency, reliability, and accuracy.

References

1. Jeon, Y.J., Park, S.H., Kang, S.J.: Self-x based closed loop wearable IoT for real-time detection and resolution of sleep apnea. Internet of Things **22**, 100767 (2023)
2. Kelvin-Agwu, M.C., Mustapha, A.Y., Mbata, A.O., Tomoh, B.O., Forkuo, A.Y.: Development of AI-assisted wearable devices for early detection of respiratory diseases. Int. J. Multidiscip. Res. Growth Eval. **4**(1), 967–974 (2023)
3. Almuhanna, H., Alenezi, M., Abualhasan, M., Alajmi, S., Alfadhli, R., Karar, A.S.: AI asthma guard: predictive wearable technology for asthma management in vulnerable populations. Appli. Syst. Innovation **7**(5), 78 (2024)
4. Robin, C.R.R., Thuhfa, M.A.: Smart health monitoring for industrial workers: a predictive IoT solution for COPD and Asthma. In: 2025 International Conference on Computing and Communication Technologies (ICCCT), pp. 1–6. IEEE (2025)
5. Michael, I.: IoT Wearables for Sleep Apnea Diagnosis and Monitoring (2024)
6. Fakhrulddin, S.S., Bhatt, V.: Wearable biosensors and devices for lung function monitoring. Progress Molecular Biol. Trans. Sci. **215**, 355–384 (2025)
7. Pan, Z., et al.: Screening and early warning system for chronic obstructive pulmonary disease with obstructive sleep apnoea based on the medical Internet of Things in three levels of healthcare: protocol for a prospective, multicentre, observational cohort study. BMJ Open **14**(2), e075257 (2024)
8. Aghalya, S., Venkatesvara Rao, N., Reena Roy, R., Srinivasan, C., Premi, G.: Real-time monitoring and prediction of respiratory diseases using IoT and machine learning. In: 2023 Second International Conference on Smart Technologies for Smart Nation (SmartTechCon), pp. 635–640. IEEE (2023)

9. Jacob, D., Kokil, P., Subramanian, S., Jayanthi, T.: Wearable sensor design for real-time obstructive sleep apnea monitoring. IEEE Sensors J. (2025)
10. Mangayarkarasi, T., Parnika, S., Abirami, S., Jayashree, K., Nalini, C.: Smart Jacket: integrated sensor system for real-time COPD and sleep apnea monitoring. In: 2024 International Conference on Power, Energy, Control and Transmission Systems (ICPECTS), pp. 1–6. IEEE (2024)