IoT – Driven Sleep Apnea Detection

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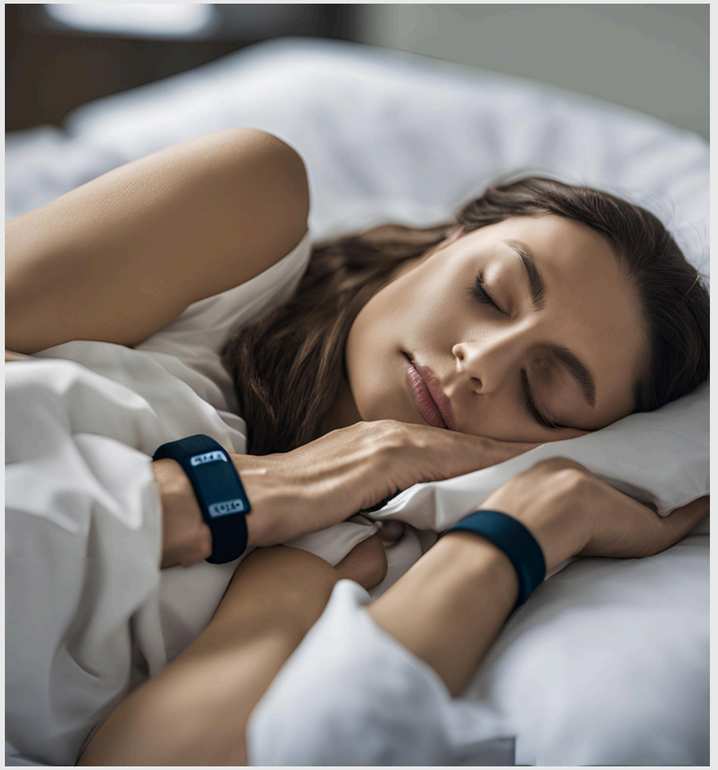
Project Overview

The project involves developing a wearable wristband capable of monitoring physiological parameters like:

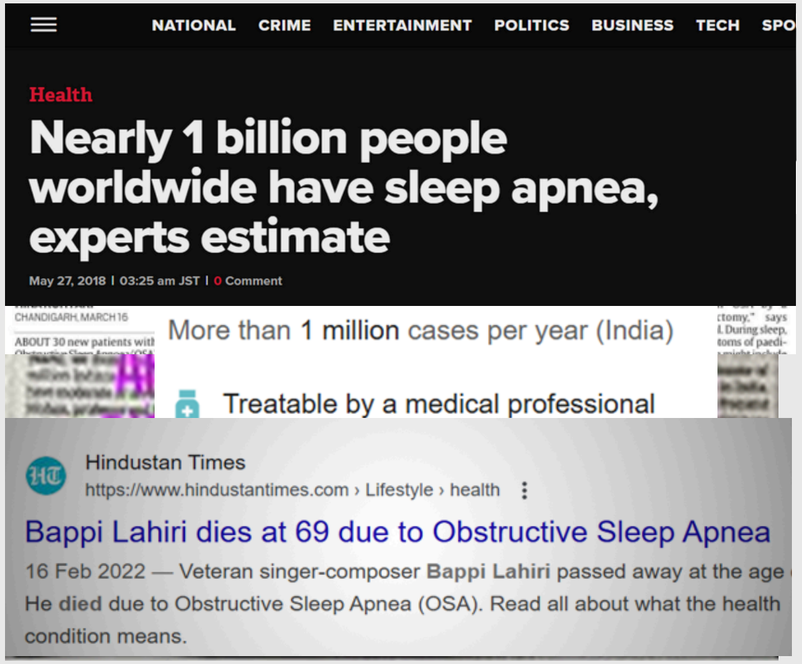
- Heart Rate Variability (HRV)
- Oxygen Saturation (SpO_2)
- Electrocardiogram (ECG)
- Respiration

This device will use sensor technology and AI-based algorithms to detect sleep apnea episodes and provide real-time data analysis. The data will be processed and visualized in a mobile or web-based dashboard for users and healthcare professionals.

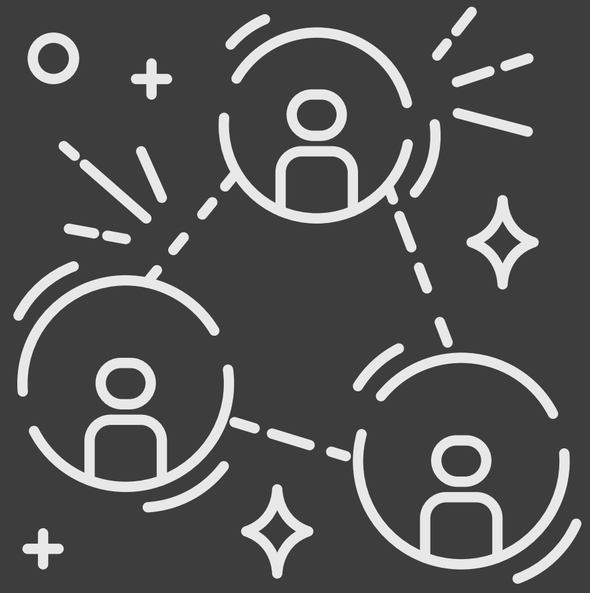


Need Analysis

- High Prevalence of Sleep Apnea – Millions remain undiagnosed.
- Health Complications – Linked to heart disease, diabetes, and cognitive issues.
- Limitations of Traditional Methods – Polysomnography (PSG) is expensive and inconvenient
- Advantages of IoT-Based Solution – Non-intrusive, continuous monitoring, remote accessibility.



Related Work



- Polysomnography (PSG) in Sleep Labs

  Gold standard but costly, inconvenient, and requires medical supervision.
- Consumer Wearables (e.g., Fitbit, Apple Watch, Oura Ring)

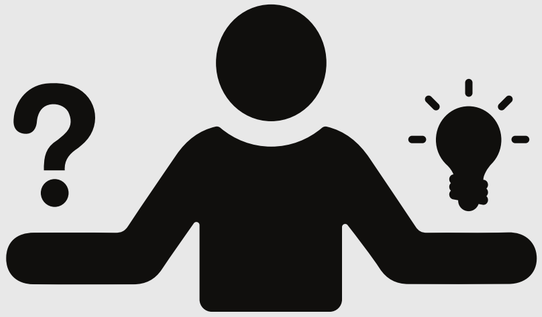
  Measure HRV and SpO_2 but lack direct apnea detection and accuracy.
- Existing Wearable Solutions (e.g., Withings Sleep Analyzer, Go2Sleep)

  Some wearables provide sleep tracking but are not as comprehensive in detecting apnea episodes based on multiple parameters.
- AI-based Research Models

  Studies on deep learning & signal processing for apnea detection show promising results but require real-world validation.

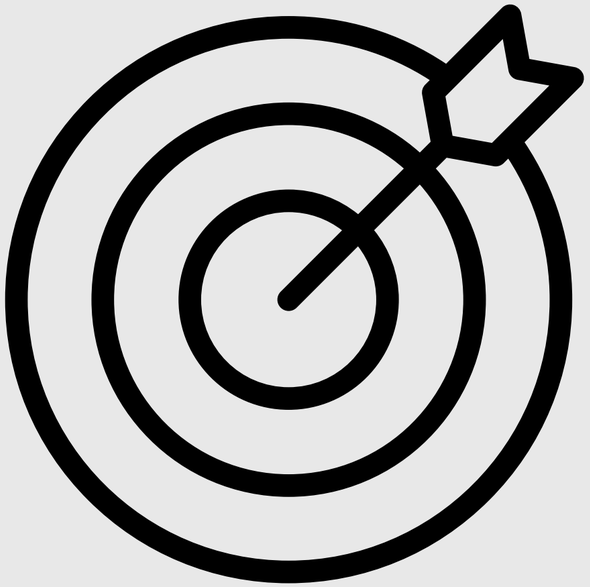
Problem Statement

Sleep apnea is a serious sleep disorder where breathing repeatedly stops and starts, leading to poor sleep quality, daytime fatigue, and severe health issues such as hypertension, heart disease, and diabetes. Traditional diagnostic methods, such as polysomnography (PSG) in sleep labs, are expensive, inconvenient, and require specialized medical supervision. There is a need for an accessible, affordable, and non-invasive solution for early detection and continuous monitoring of sleep apnea.



Objectives

- Accurate Detection of Sleep Apnea using multi-sensor data
- AI-Driven Real-Time Analysis for early detection.
- Seamless remote data accessibility and monitoring to ensure accessibility.
- Continuous, Non-Intrusive Monitoring for early intervention.
- Scalable & Wearable-Friendly Design for user comfort.



Assumptions and Constraints

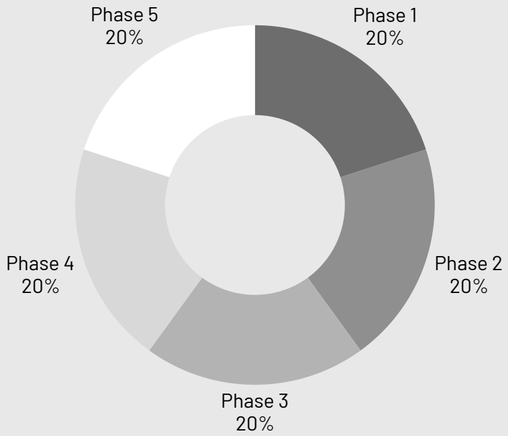
- Users correctly wear the wristband.
- Sensors deliver reliable data under typical conditions.
- The AI model effectively generalizes across different users.

- Battery life limitations for wearable devices.
- Data privacy and security concerns.
- Environmental factors affecting sensor accuracy.

Execution Plan

Phase 1: Research & Feasibility Study

- Study existing diagnostic tools and sensor technologies.
- Identify suitable biosensors and machine learning models.



Phase 2: Hardware Development

- Integrate sensors for ECG, SpO_2, HRV, and respiration.
- Prototype a comfortable and power-efficient device.

Phase 3: Software & AI Integration

- Develop firmware to collect and transmit sensor data.
- Implement AI-based apnea detection algorithms.
- Build a web or mobile-based monitoring dashboard.

Phase 4: Testing & Validation

- Conduct trials on healthy individuals and apnea patients.
- Compare results with polysomnography (PSG) data.

Phase 5: Optimization & Deployment

- Improve algorithm accuracy and power efficiency.
- Ensure regulatory compliance for medical use.

Requirements

Sensor/Parameter	Role	Cost	Data collected
MAX30102 (SpO_2)	Integrated SpO_2 and heart rate sensor	₹80 - ₹350	Blood oxygen saturation, heart rate
ADS1292R (Respiration)	Bioimpedance-based respiration and ECG sensor	₹3,500 - 4,000	Respiration rate, Electrical Activity of Heart
AD8232 (ECG)	Single-lead ECG sensor for wearable applications	₹300 - 1,000	Electrical activity of heart
MAX30105 (HRV)	PPG-based HRV measurement sendor	₹300 - 800	Heart rate variability

Outcomes

1

Accurate Sleep Apnea Detection – Improved classification by fusing SpO_2, HRV, respiration, and ECG data.

2

Real-Time Monitoring & Alerts – Instant notifications to users and caregivers.

3

Cost-Effective & Non-Intrusive Design – Comfortable wearable with remote monitoring features.

4

CPAP automation for performing adaptive breathing assistance.

Work Plan

Phase 1: Research & Feasibility Study

(Jan 2025 - Feb 2025)

- Study existing diagnostic tools and sensor technologies.
- Identify suitable biosensors and machine learning models.

Phase 2: Hardware Development

(Mar 2025 - Jun 2025)

- Integrate sensors for ECG, SpO_2, HRV, and respiration.
- Prototype a comfortable and power-efficient device.

Phase 3: Software & AI Integration

(Jun 2025 - Aug 2025)

- Develop firmware to collect and transmit sensor data.
- Implement AI-based apnea detection algorithms.
- Build a web or mobile-based monitoring dashboard.

Phase 4: Testing & Validation

(Sep 2025 - Oct 2025)

- Conduct trials on healthy individuals and apnea patients.
- Compare results with polysomnography (PSG) data.

Phase 5: Optimization & Deployment

(Nov 2025 - Dec 2025)

- Improve algorithm accuracy and power efficiency.
- Ensure regulatory compliance for medical use.

Individual Roles

(102203180) Baneet Singh - Model Development & Documentation

(102217058) Armaan Saini - Model Development & UI Development

(102217071) Ramitdeep Kaur - Model Development & UI Development

(102203208) Babandeep Kaur - IoT Integration & Documentation

(102203242) Mehakdeep Kaur - IoT Integration & UI Development

References

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