UNIVERSITY OF GHANA

LIFEGUARD:
WEARABLE HEALTH AND ENVIRONMENTAL MONITORING SYSTEM V2.2

PROJECT PROPOSAL

Project Members
Evans Acheampong
Michael Adu-Gyamfi

Project Supervisor
Dr. Percy Okae

Ambassador, Embedded Learning Challenge
Marvin Rotermund

VERSION HISTORY

Version	Release Date	Author(s)	Changes made
1.0	20/11/2024	E. Acheampong, M. Adu-Gyamfi	Initial draft
2.0	12/12/2024	E. Acheampong, M. Adu-Gyamfi	Added in-depth project timeline and modified styling
2.1	17/12/2024	E. Acheampong, M. Adu-Gyamfi	Added target audience, cost analysis and proposed system overview based on Marvin Rotermund’s feedback
2.2	30/12/2024	E. Acheampong, M. Adu-Gyamfi	Updated technical specifications, architecture, implementation timeline, etc. (detailed in Change log)

CHANGE LOG – VERSION 2.2

Documentation Improvements

- Standardized formatting across all sections with page numbering
- Enhanced version control and change log
- Updated implementation timeline
- Updated mobile designs
- Included Marvin Rotermund as Ambassador, Embedded Learning Challenge

Technical Enhancements

- Updated power optimization strategy using low power sensors and LIPO battery
- Enhanced System Architecture with clear input, processing and output layers
- Transitioned from Arduino Cloud to Custom Backend
- Added roles and responsibilities for each team member

TABLE OF CONTENT

- EXECUTIVE SUMMARY
- INTRODUCTION
- PROBLEM DEFINITION
- RELEVANCE OF WORK
- AIMS & OBJECTIVES
- TARGET AUDIENCE & ECOSYSTEM
- UNIQUE VALUE PROPOSITION
- COMPETITIVE ANALYSIS
- LITERATURE REVIEW/EXISTING WORKS
- SYSTEM REQUIREMENTS
- REAL WORLD APPLICATIONS
- MOBILE APP DESIGNS
- BILL OF MATERIALS

TABLE OF CONTENT

- WORKING SYSTEM OVERVIEW
- TECHNOLOGIES USED
- PROPOSED SYSTEM ARCHITECTURE
- PROPOSED DATA FLOW DIAGRAM
- DATABASE SCHEMA RELATIONSHIPS
- PICTORIAL VIEW OF PROPOSED
- SYSTEM OVERVIEW
- TECHNICAL CHALLENGES
- DESIGN & IMPLEMENTATION
- CHALLENGES
- ROLES & RESPONSIBILITIES
- IMPLEMENTATION TIMELINE
- DISCUSSION & CONCLUSION
- REFERENCES

EXECUTIVE SUMMARY

- The LifeGuard project is an innovative health and environmental monitoring system that addresses critical gaps in personal safety, accessibility, and preventive healthcare.
- By integrating advanced sensors with machine learning, it delivers real-time data on health metrics such as heart rate and activity, alongside environmental parameters like air quality.
- LifeGuard stands out as a cost-effective and comprehensive alternative to premium devices, enabling equitable access for underserved populations, including the elderly and industrial workers in developing regions.
- The device’s user-centric design and affordability make it a scalable solution to promote proactive health and safety management globally.

INTRODUCTION

- Current health and environmental monitoring systems often rely on multiple devices, resulting in higher costs, increased complexity, and limited accessibility. Many existing solutions fail to provide real-time alerts or comprehensive data, leaving critical gaps in timely intervention and preventive healthcare.

- LifeGuard, powered by the advanced **Nicla Sense ME** board, integrates nine sensors to deliver seamless real-time monitoring of health metrics and environmental conditions. The system employs sophisticated motion detection algorithms and environmental sensing, creating a holistic safety monitoring solution for proactive risk identification.

- With features like fall detection, physical activity recognition, environmental condition assessment, and air quality analysis, LifeGuard represents a cost-effective and integrated solution for personal protection and well-being.

PROBLEM DEFINITION

- Most market solutions rely on multiple devices for health and environmental monitoring, leading to higher costs and added complexity.

- Need for comprehensive safety monitoring for vulnerable populations. This ensures proactive identification of risks and timely intervention to safeguard their well-being.

- Many existing solutions fail to provide real-time alerts and updates, limiting their ability to respond promptly to critical situations.

- Growing demand for preventive healthcare technology. This shift highlights the importance of innovative solutions that empower individuals to monitor and manage their health before conditions escalate.

RELEVANCE OF WORK

➢ Aging Population

WHO reports **28-35%** of people aged 65+ fall each year, highlighting the urgent need for advanced fall detection systems and general health monitoring to reduce injuries, hospitalizations, and improve quality of life for the elderly.

➢ Environmental Concerns

Environmental health concerns, especially air quality, affect public health, with **99%** of the global population exposed to unsafe pollution levels, leading to over 7 million premature deaths annually (World Health Organization, Environmental Health Impact Report, October 2024).

RELEVANCE OF WORK

➢ Healthcare Costs

Cost-effective solutions needed to make safety monitoring accessible to broader populations. This will help bridge the gap in safety monitoring, ensuring equitable protection for underserved communities.

➢ Industrial Safety

Rising industrial accidents due to environmental hazards necessitate real-time monitoring solutions. Proactive detection and response systems can significantly reduce risks, safeguarding both workers and assets.

AIMS & OBJECTIVES

- **Integrated Monitoring System**

Develop an integrated health and environmental monitoring system

- **Fall Detection and Activity Recognition**

Implement real-time fall detection and activity recognition

- **Environmental Condition Monitoring**

Create comprehensive environmental condition monitoring

- **Alert System**

Establish efficient alert system for emergency situations

- **User Interfaces**

Design user-friendly mobile and web interfaces

TARGET AUDIENCE & ECOSYSTEM

Primary Target Groups

- Aging population(55+) years: Addressing fall risks and respiratory health.
- Health-conscious individuals(25-54 years): Personal wellness tracking.
- Industrial workers: Mitigating risks in hazardous environments.
- Healthcare Providers: Remote monitoring programs & Home care services

Relevance to Developing Countries

- Affordable pricing ensures accessibility in low-resource settings.
- Real-time alerts and preventive features reduce reliance on reactive healthcare systems.
- Local adaptation through customizable features.

UNIQUE VALUE PROPOSITION

Price Point

- Approximately 60 % cheaper than an Apple Watch
- Approximately 50% cheaper than a Samsung Watch
- Premium features at affordable price

Feature Integration

- Combined health and environmental monitoring
- Local emergency response integration
- Family sharing capabilities
- Local adaptation through customizable features.

COMPETITIVE ANALYSIS

Feature	LifeGuard	Apple Watch	Samsung Watch	Mi Band
Base Price	$160	$399	$280	$50
Health Monitoring	✓	✓	✓	✓
Environmental Monitoring	✓	×	×	×
Fall Detection	✓	✓	✓	×
Local Emergency Integration	✓	×	×	×
Battery Life	72h	18h	40h	14d
Water Resistance	IP67	IP68	IP68	IP67
Local Health Provider Integration	✓	×	×	×

LITERATURE REVIEW/EXISTING WORKS

Author(s)	Title	Overview	Achieved	Gap
D. Hemapriya; Pavithra Viswanath; V. M. Mithra; [2019]	Wearable medical devices: Design challenges and issues	Comprehensive analysis of wearable medical device design	Identified key challenges in wearable device development	Limited focus on environmental monitoring integration
Rahul K. Kher, Dipak M. Patel [2021]	A Comprehensive Review on Wearable Health Monitoring System	Analysis of existing health monitoring systems	Cataloged various monitoring approaches	Lack of real-time environmental factor correlation
Wang, Z., Yang, Z., & Dong, T. [2020]	A Comprehensive Review of Wearable Health Monitoring Devices with Integrated Sensors	Examines devices integrating health and environmental data.	Discusses sensor fusion for combined data collection.	Limited focus on real-time data fusion and actionable insights.

LITERATURE REVIEW/EXISTING WORKS

Author(s)	Title	Overview	Achieved	Gap
Patel, R., Johnson, M., & Smith, K. [2020]	Wearable Sensors Data-Fusion and Machine-Learning Method for Fall Detection and Activity Recognition	Investigates the integration of gas sensing and physiological metrics in wearables.	Identified potential for holistic monitoring.	Lack of real-world testing for multi-sensor devices.
Hernandez, J., Liu, Y., & Park, S. [2020]	ML Approaches for Fall Detection and Activity Recognition in Wearables	Analyzes AI models for activity and fall detection.	Validated AI models for specific use cases like fall detection.	No combined analysis with health metrics such as heart rate variability.

SYSTEM REQUIREMENTS

Functional Requirements

- Real-time health monitoring
  - Fall detection
  - Activity recognition
- Environmental monitoring
  - Temperature sensing
  - Humidity monitoring
  - Air quality analysis
- Alert system
  - Emergency notifications
  - Automated emergency contact
  - Custom alert thresholds

Non-Functional Requirements

- Performance
  - 24/7 operation capability
  - 99.9% system uptime
- Security
  - End-to-end encryption
  - HIPAA compliance
  - Secure data storage
- Usability
  - Intuitive interface
  - Long lasting Battery life
  - Water-resistant design

REAL WORLD APPLICATIONS

Healthcare

- Remote Patient Monitoring
- Early warning system for respiratory issues
- Fall prevention for elderly
- Emergency response automation

Industrial Safety

- Worker safety in hazardous environments
- Air quality monitoring in confined spaces
- Air Quality triggers

REAL WORLD APPLICATIONS

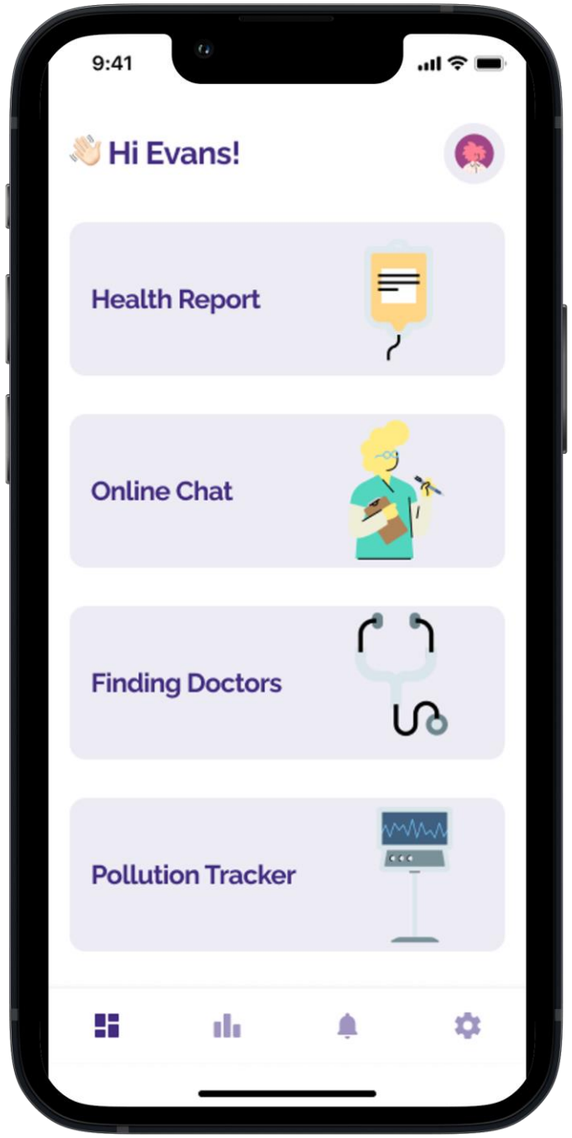
Personal Wellness

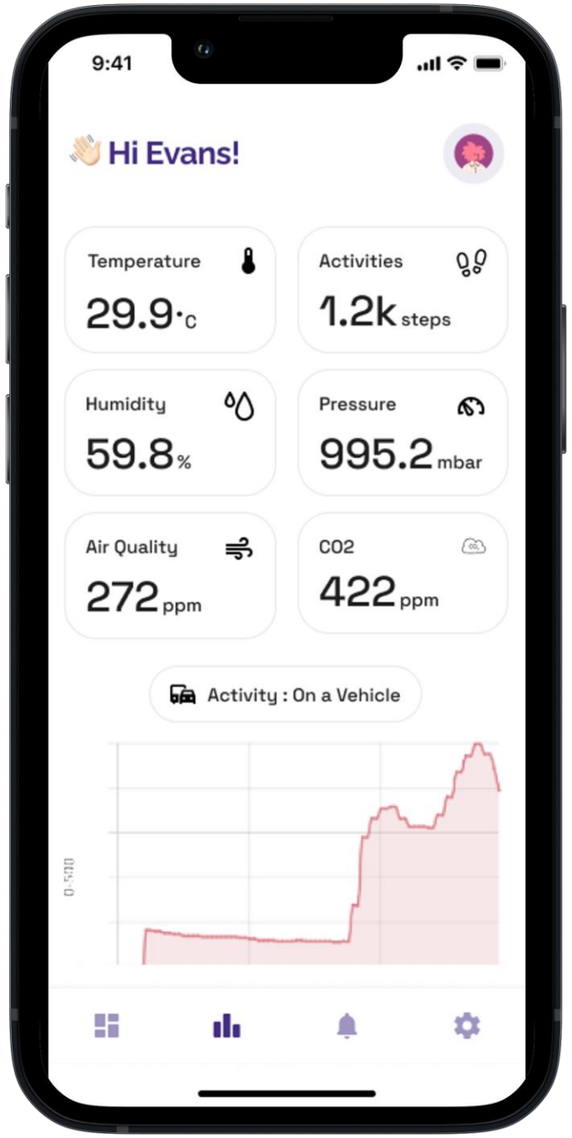
- Environmental impact on health tracking
- Exercise condition monitoring such as Walking, Running, Jumping, Sitting, etc.
- Indoor air quality alerts for gases such as Volatile Organic Compounds (VOCs), Volatile Sulfur Compounds (VSCs), Carbon Monoxide and Hydrogen in the ppb range.
- Weather-related health warnings
- Real-time location
- Emergency contact and alert system

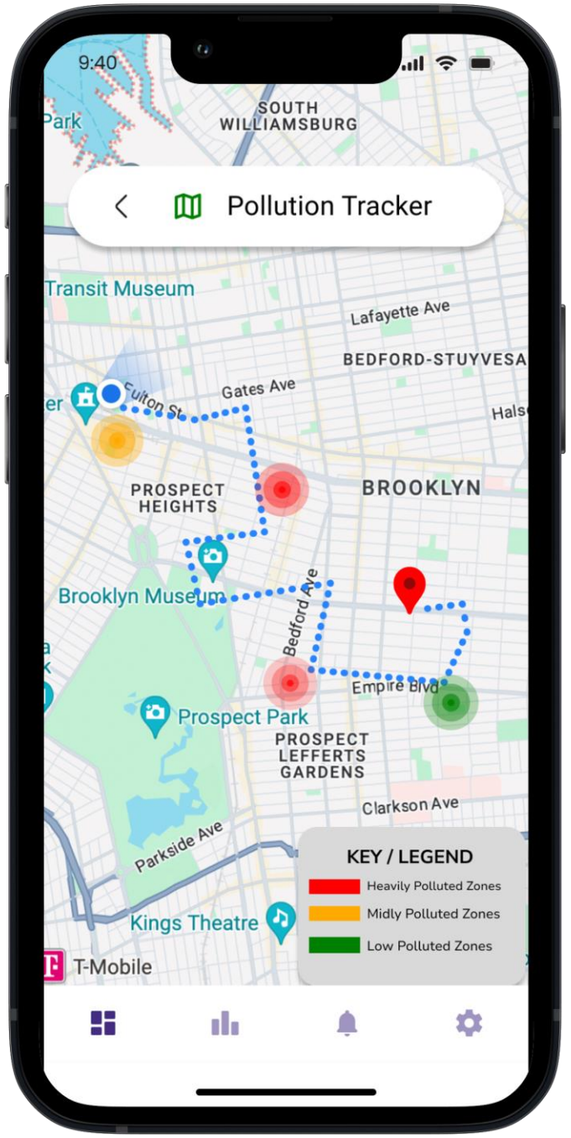
Outdoor Recreation

- Adventure sports activity tracking such as Push-ups, Squats, Cycling, etc
- Environmental condition alerts
- Weather hazard warnings

MOBILE APP DESIGNS







BILL OF MATERIALS

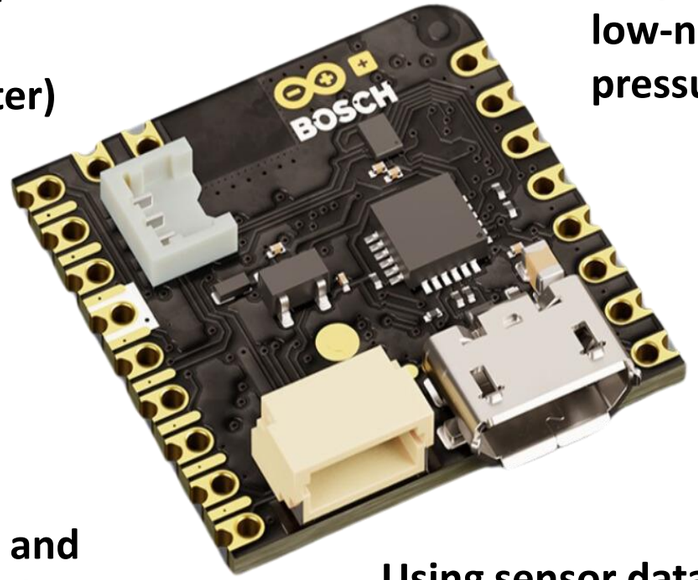
Item	Cost (GH₵)	Quantity	Total (GH₵)
Arduino Nicla Sense ME	1200	1	1200
LiPo Battery – 3.7V	50	1	50
Custom enclosure & Assembly	500	1	500
Total Estimate (Unit Cost)			**1750 ≈ (2000 – 2500)**

This cost is significantly lower than premium devices like the Apple Watch (~**GH₵15,000**).

Comparison: LifeGuard's affordability ensures accessibility without compromising functionality, meeting the unique needs of developing countries.

WORKING SYSTEM OVERVIEW

Smart Sensor System with Built-in 6-Axis IMU (gyroscope & accelerometer)



Very small, low-power and low-noise absolute barometric pressure sensor.

The first gas sensor with AI and integrated high-linearity and high-accuracy pressure, humidity, gas and temp. sensors.

Using sensor data fusion, it provides absolute spatial orientation and motion vectors with high accuracy and dynamics.

Nicla Sense ME board with **9 integrated sensors**

Real-time data processing and analysis

Mobile and web applications for remote monitoring

TECHNOLOGIES USED

Core Hardware Components

- Arduino Nicla Sense ME board
- LiPo battery(3.7V, 400mAh)
- Custom-designed enclosure

Sensors (built-in)

- Accelerometer & Gyroscope (Motion detection)
- Temperature & Humidity sensors
- Barometric pressure sensor
- Magnetometer

TECHNOLOGIES USED

Software Stack

Frontend Technologies

- React (Web Dashboard)
- Chart JS
- Flutter (Mobile App)
- TypeScript
- Tailwind CSS
- Redux (State management)

Backend Technologies

- Firebase
- .NET
- PostgreSQL

TECHNOLOGIES USED

Hosting Services

- Vercel (Web Hosting)
- Render (Backend Hosting)
- NEON.TECH (Database Hosting)

Machine Learning & Analytics

- Edge Impulse (Activity Recognition)
- Custom ML models for pattern detection
- Data analysis tools
- Pollution map & analytics using

Google Map API / Open Street Map

Authentication & Security

- Google Authentication
- Oauth 2.0
- End-to-end encryption
- Secure boot implementation

PROPOSED SYSTEM ARCHITECTURE

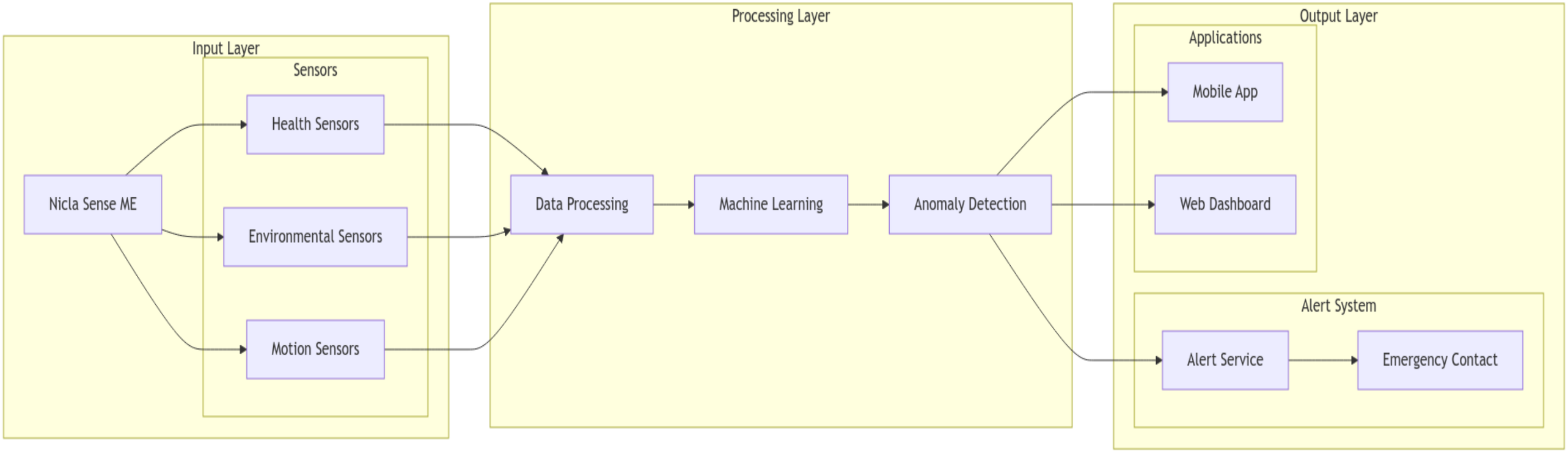


Figure 1: Proposed System Architecture

PROPOSED DATA FLOW DIAGRAM

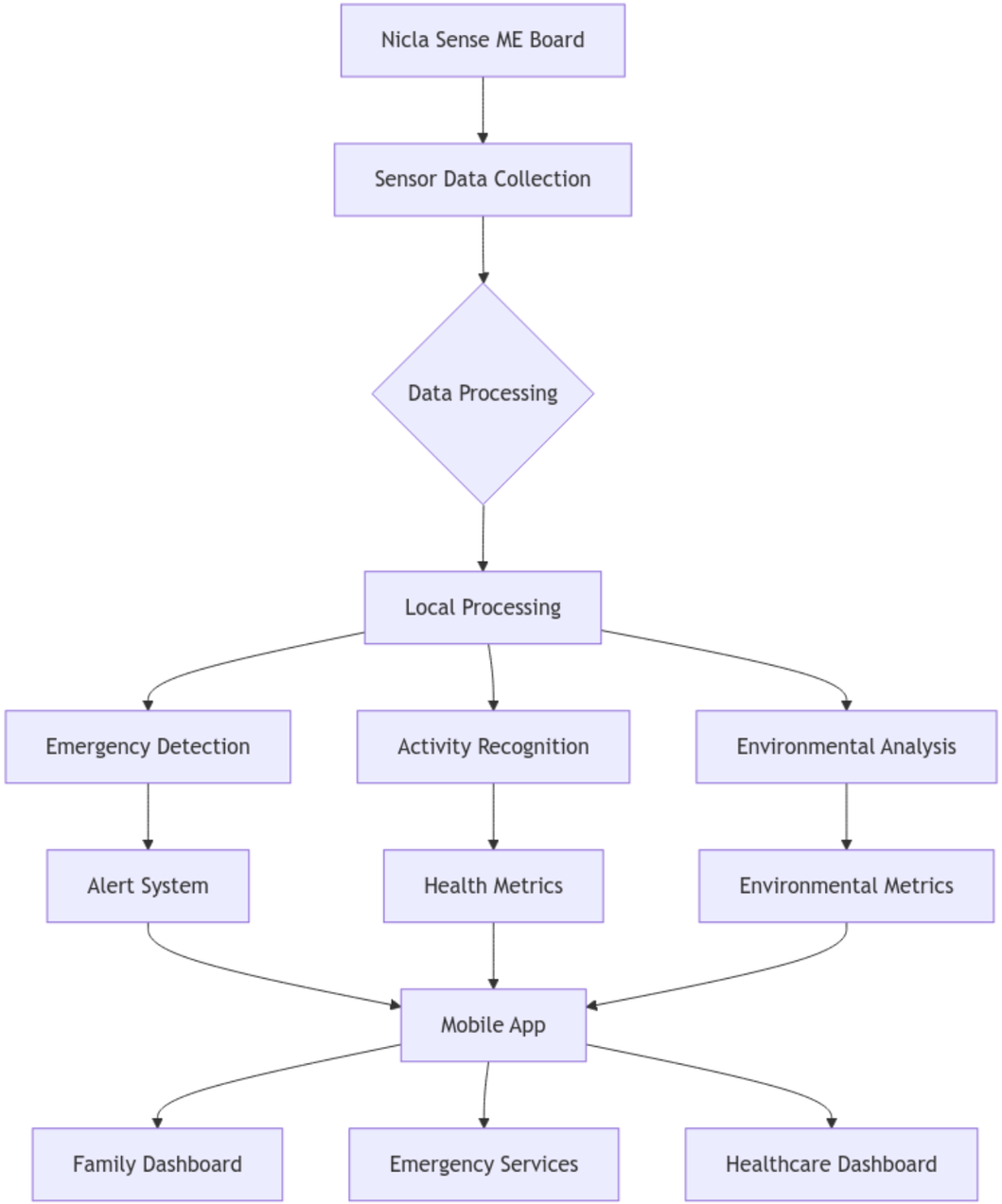


Figure 2: Proposed Data Flow Diagram

DATABASE SCHEMA RELATIONSHIPS

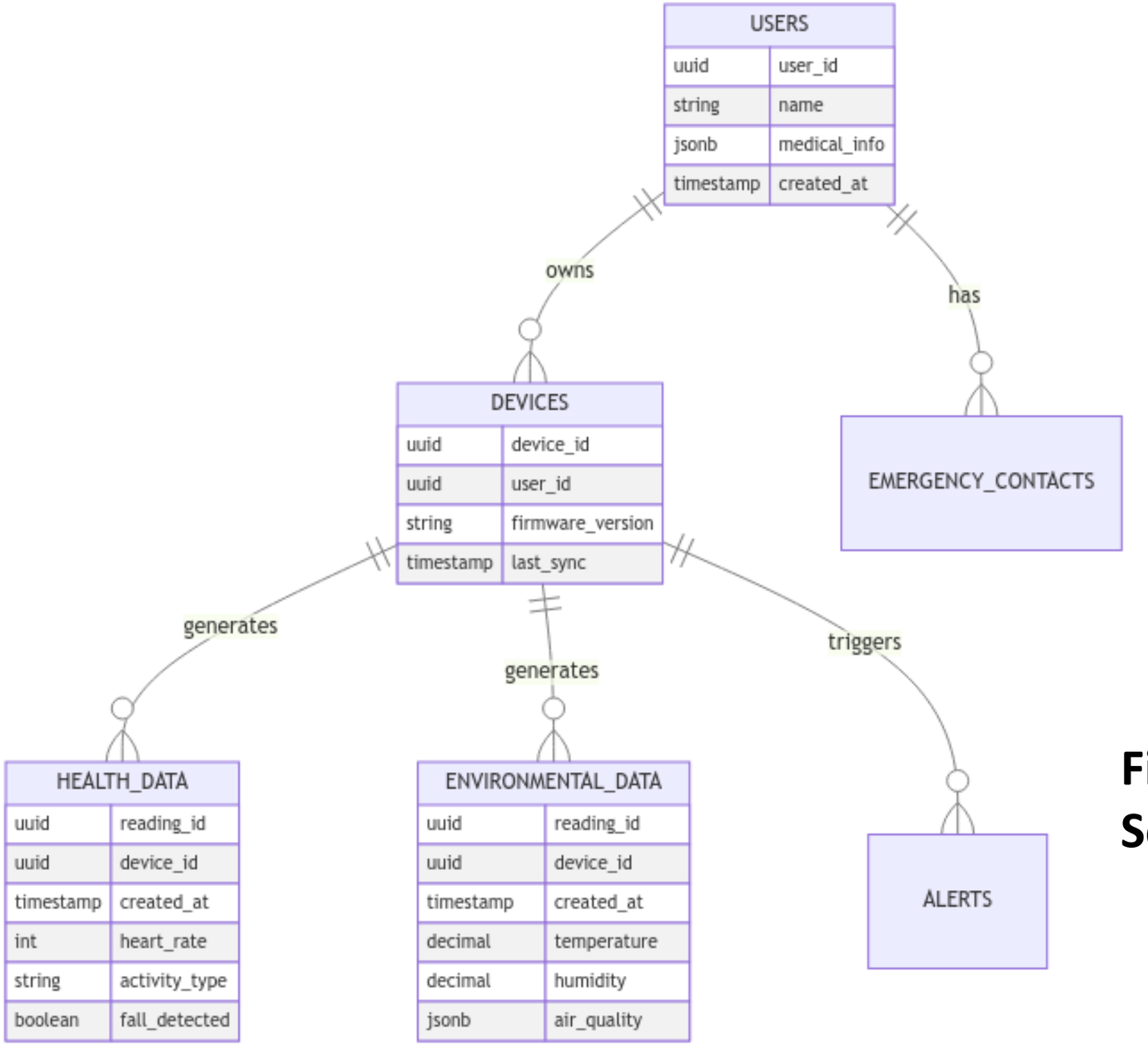


Figure 4: Database Schema Relationships

PICTORIAL VIEW OF PROPOSED SYSTEM OVERVIEW

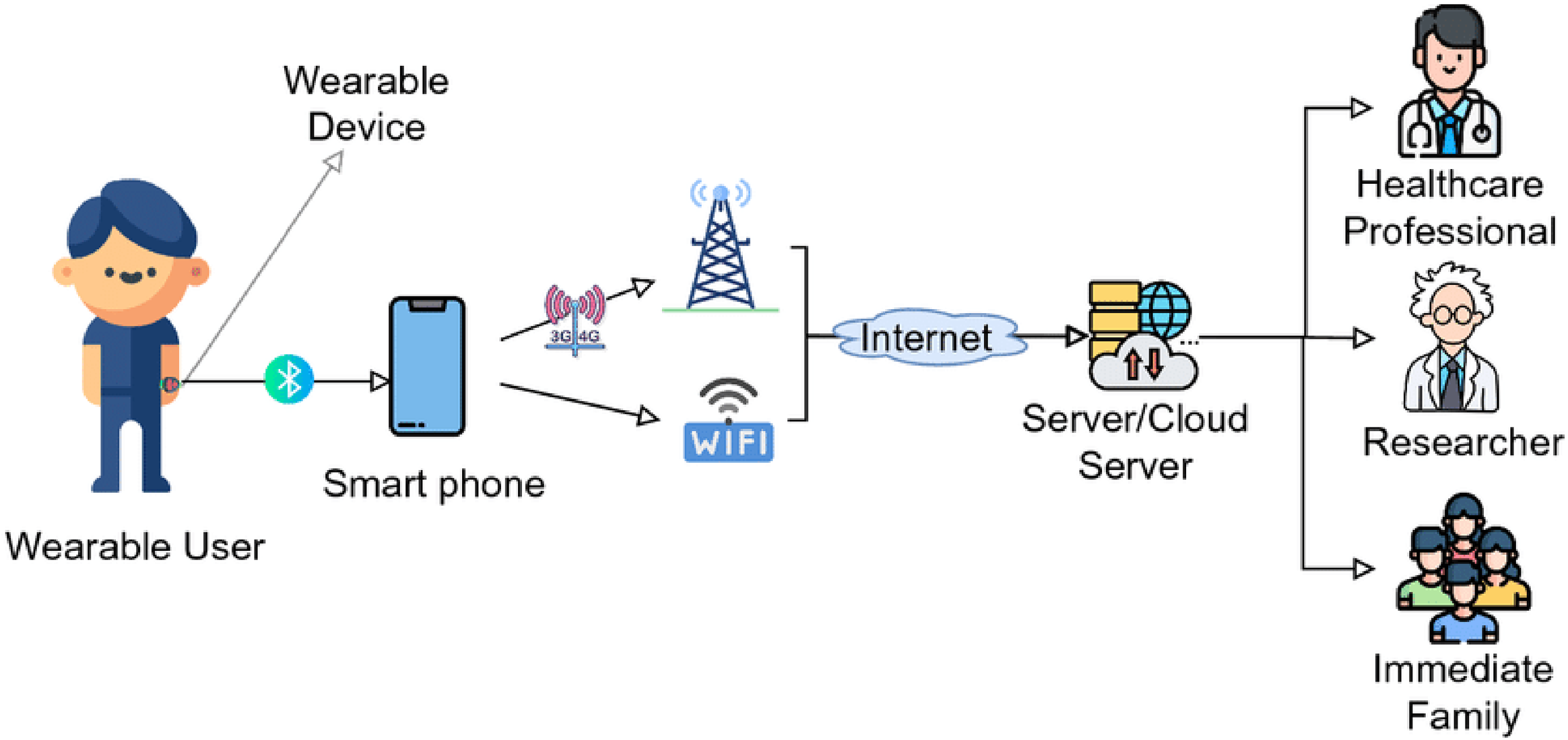


Figure 5: Pictorial view of proposed system overview – [7]

TECHNICAL CHALLENGES

Power Management & Battery Life

- Optimizing power consumption for continuous 24/7 monitoring using a 400mAh battery
- Balancing sensor sampling rates with battery efficiency
- Implementing effective power-saving modes without compromising functionality

Real-time Processing & Communication

- Implementing efficient data processing at the edge
- Managing continuous data streaming over BLE
- Ensuring reliable wireless connectivity in various environments
- Handling potential network latency and disconnections

TECHNICAL CHALLENGES

Sensor Accuracy & Calibration

- Ensuring precise fall detection with minimal false positives
- Achieving reliable sensor fusion for combined data analysis

Data Management & Storage

- Implementing efficient local data caching
- Managing hosting server storage limitations
- Optimizing data synchronization processes
- Ensuring data integrity across platforms

DESIGN & IMPLEMENTATION CHALLENGES

Hardware Design

- Creating a water-resistant enclosure
- Ensuring comfortable wearability for long-term use
- Managing heat dissipation
- Integrating multiple sensors in a compact form factor

Safety & Reliability

- Implementing fail-safe mechanisms
- Ensuring accurate emergency detection
- Managing false alerts
- Maintaining device durability

DESIGN & IMPLEMENTATION CHALLENGES

User Experience

- Designing an intuitive mobile interface
- Implementing clear and effective alert systems
- Balancing feature complexity with ease of use
- Creating meaningful data visualizations

Security & Privacy

- Implementing robust data encryption
- Ensuring secure device-server communication
- Managing user authentication and authorization
- Complying with health data privacy regulations

ROLES & RESPONSIBILITIES

Team Member	Key Focus Areas
Evans Acheampong	Frontend development (React, React Native), hardware and sensor integration, and user interface testing/documentation.
Michael Adu-Gyamfi	Backend development (.NET, PostgreSQL), machine learning, data analytics and system security (encryption, CI/CD).

IMPLEMENTATION TIMELINE

Phase 1: Development (Jan 2025 – Mar 2025)

Week	Milestone	Deliverable	Dependencies
1-2	Hardware Setup	Functioning prototype	Component delivery
3-4	Sensor Integration	Data collection system	Hardware setup
5-6	ML Model Development	Initial models	Training data
7-8	Mobile App Development	Basic app interface	API design
9-10	Server Infrastructure	Database & API	Architecture design
11-12	Integration	Working system	All components

IMPLEMENTATION TIMELINE

Phase 2: Testing (Apr 2025 – Jun 2025)

Week	Milestone	Deliverable	Dependencies
1-4	Unit Testing	Test reports	Development completion
5-8	Integration Testing	System validation	Unit testing
9-12	User Testing	Feedback analysis	Beta version

IMPLEMENTATION TIMELINE

Phase 3: Deployment (Jul 2025 – Aug 2025)

Week	Milestone	Deliverable	Dependencies
1-4	Production Setup	Manufacturing line	Testing completion
5-6	Initial Production	First batch	Production setup
7-8	Market Launch	Product release	Quality validation

DISCUSSION & CONCLUSION

Discussion

- Proposed system aims to bridge critical gap between health and environmental monitoring
- Integration of Nicla Sense ME board offers comprehensive sensor capabilities at reasonable cost
- Client-Server architecture enables scalable solution for various user groups

Conclusion

- LifeGuard represents innovative approach to integrated safety monitoring
- Potential impact spans healthcare, industrial safety, and personal wellness
- Project lays foundation for future development in wearable safety technology

REFERENCES

[1] Wang, Z., Yang, Z., & Dong, T. (2023). "A Comprehensive Review of Wearable Health Monitoring Devices With Integrated Environmental Sensors." IEEE Sensors Journal, 23(2), 1121-1134.

[2] Kumar, S., Zhang, Y., & Chen, M. (2022). "IoT-Based Fall Detection Systems for Elderly Care: A Systematic Review." IEEE Internet of Things Journal, 9(4), 2331-2346.

[3] Patel, R., Johnson, M., & Smith, K. (2023). "Integration of Environmental and Physiological Monitoring in Smart Wearables." Sensors and Actuators B: Chemical, 378, 132654.

[4] Li, X., Chen, H., & Williams, D. (2022). "Real-time Health and Environmental Monitoring Using Multi-sensor Fusion." Journal of Healthcare Engineering, 2022, 9876543.

[5] Hernandez, J., Liu, Y., & Park, S. (2023). "Machine Learning Approaches for Fall Detection and Activity Recognition in Wearable Devices." ACM Transactions on Embedded Computing Systems, 22(3), 1-25.

[6] Rodriguez, A., Kim, J., & Thompson, B. (2022). "Cloud-Based Architecture for Personal Health Monitoring Systems." IEEE Transactions on Cloud Computing, 10(2), 456-469.

[7] Munshi Saif, Tajkia, etc. (2022). “A systematic literature review on wearable health data publishing under differential privacy ”Journal of Medical Systems, 47(1), 1-15.

THANK YOU!