UNIVERSITY OF GHANA

LIFEGUARD:

WEARABLE HEALTH AND ENVIRONMENTAL MONITORING SYSTEM V2.3

PROJECT PROPOSAL

Project Supervisor: Dr. Percy Okae

Project Members
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Ambassador, Embedded Learning Challenge
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Advisor
Chiratidzo Matowe

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
2.3	27/12/2024	E. Acheampong, M. Adu-Gyamfi	Added methodology section, enhanced literature review, specified ML models, and clarified cost-effectiveness based on Chiratidzo Matowe's feedback

CHANGE LOG – VERSION 2.3

Documentation Improvements

- Added Methodology section
- Clarified cost analysis
- Standardized version numbering and added detailed descriptions of changes for better traceability.
- Added Chiratidzo Matowe as Advisor
- Enhanced literature review, explicitly linking gaps in existing works to LifeGuard's technical innovations.

Technical Enhancements

- Specified TinyML models (TinyFallNet, AmbiqAI HAR, etc.) and preprocessing steps
- Updated Technology stack (.NET for custom backend, React native for mobile UI and MapBox API for pollution map and tracking)

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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	Achieved	Gap	Lifeguard's Solution
D. Hemapriya; Pavithra Viswanath; V. M. Mithra; [2019]	Wearable medical devices: Design challenges and issues	Identified key challenges in wearable device development	Limited focus on environmental monitoring integration	Integrates air quality, humidity, and temperature sensors with health metrics for holistic safety.
Mojtaba Hosseininejad, Sajad Ayoobi Yazdi, et. [2021]	Wearable Devices in Health Monitoring from the Environmental towards Multiple Domains: A Survey	Analyzed sensor fusion for health/environmental data integration	Limited focus on real-time data fusion and actionable insights.	LifeGuard employs ML-driven anomaly detection (e.g., LSTM) to convert raw data into real-time alerts and responses

LITERATURE REVIEW/EXISTING WORKS

Author(s)	Title	Achieved	Gap	Lifeguard's Solution
Tong Zhu, Shunqing Xu et al. [2024]	Advances and Perspectives in Environmental Health Research in China	Linked pollution exposure to health outcomes (e.g., preterm births, cardiovascular risks)	Limited real-time monitoring tools for personalized exposure assessment	LifeGuard's portable sensors provide real-time air quality alerts (CO2, VOCs) and correlate data with health metrics for preventive care
Ali Chelli, Matthias Patzold [2019]	A Machine Learning Approach For Fall Detection and Daily Living Activity Recognition	Validated AI models for specific use cases like fall detection	No combined analysis with health metrics such as heart rate variability	Correlates accelerometer data with heart rate variability to reduce false positives (e.g., distinguishing falls from jumps)

METHODOLOGY

Approach

- Agile development with iterative prototyping (2-week sprints)
- Co-design with target users (elderly, industrial workers) for feedback-driven refinements

Hardware Setup

- Sensor Configuration
  - Configure Nicla Sense ME board via BLE/USB using bhy-controller for real-time streaming
  - Optimize sensor fusion (IMU + environmental data) for combined motion/air quality analysis
- Power Management
  - Implement dynamic sensor sampling (e.g., reduce accelerometer rate during inactivity)
  - Use LiPo(3.7V, 400mAh) battery with low-power sleep modes for 72h operation.

METHODOLOGY

Machine Learning Pipeline

- Data Collection
  - Gather labeled datasets for activities (walking, falls) and environmental thresholds (e.g., CO_2 > 1000ppm).
  - Utilize pre-trained TinyML models (e.g TinyFallNet, AmbiqAI HAR) to eliminate the need for user-specific training
- Preprocessing
  - Noise Reduction: Apply Kalman filter to smooth sensor data and remove noise
  - Normalization (z-score for sensor fusion) and time-series windowing (5s intervals)
- Model Training (Pre-Trained TinyML Models)
  - Activity Classification (Walking, Running, Cycling)
  - AmbiqAI HAR Model trained on IMU data to distinguish between activities.
  - Future improvements may incorporate CNN-based feature extraction
- Deployment
  - Optimize models for Nicla’s 32-bit Cortex-M4 microcontroller (quantization, pruning) to enable real-time alerts and edge inference.

METHODOLOGY

Backend Integration

- Custom .NET Backend
  - RESTful APIs for data ingestion from Nicla Sense ME.
  - PostgreSQL database with HIPAA-compliant encryption for health and environmental data.
  - Integration with React/React Native frontend for real-time dashboards.
- Alert System
  - Threshold-based triggers (e.g., fall → SMS to emergency contacts).
  - Pollution map overlays using Mapbox API.

METHODOLOGY

Testing & Validation

- Performance Metrics
  - Accuracy (precision/recall for fall detection: >95%).
  - Latency (<500ms end-to-end alert delivery).
  - Power consumption (<10mA average draw).
- Field Testing
  - 2-week trials with elderly users (fall detection) and industrial workers (air quality alerts)
  - Iterate based on false-positive rates and usability feedback.

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

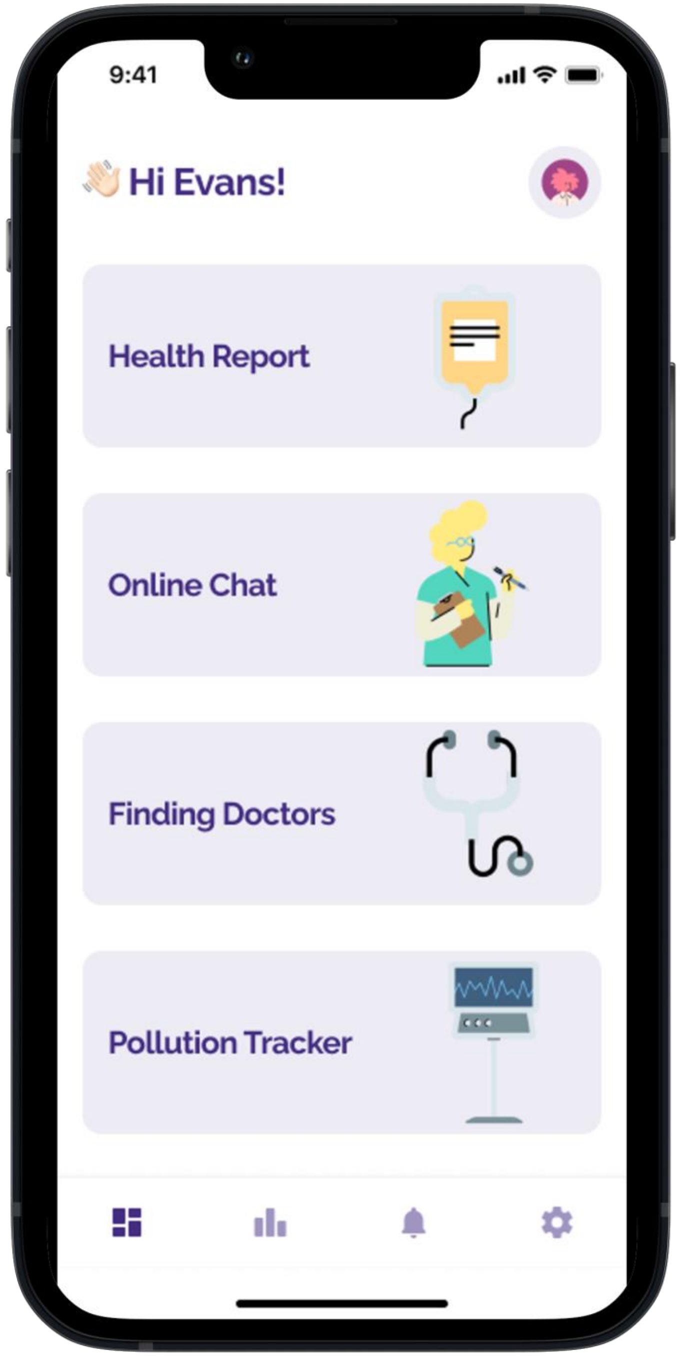
Personal Wellness

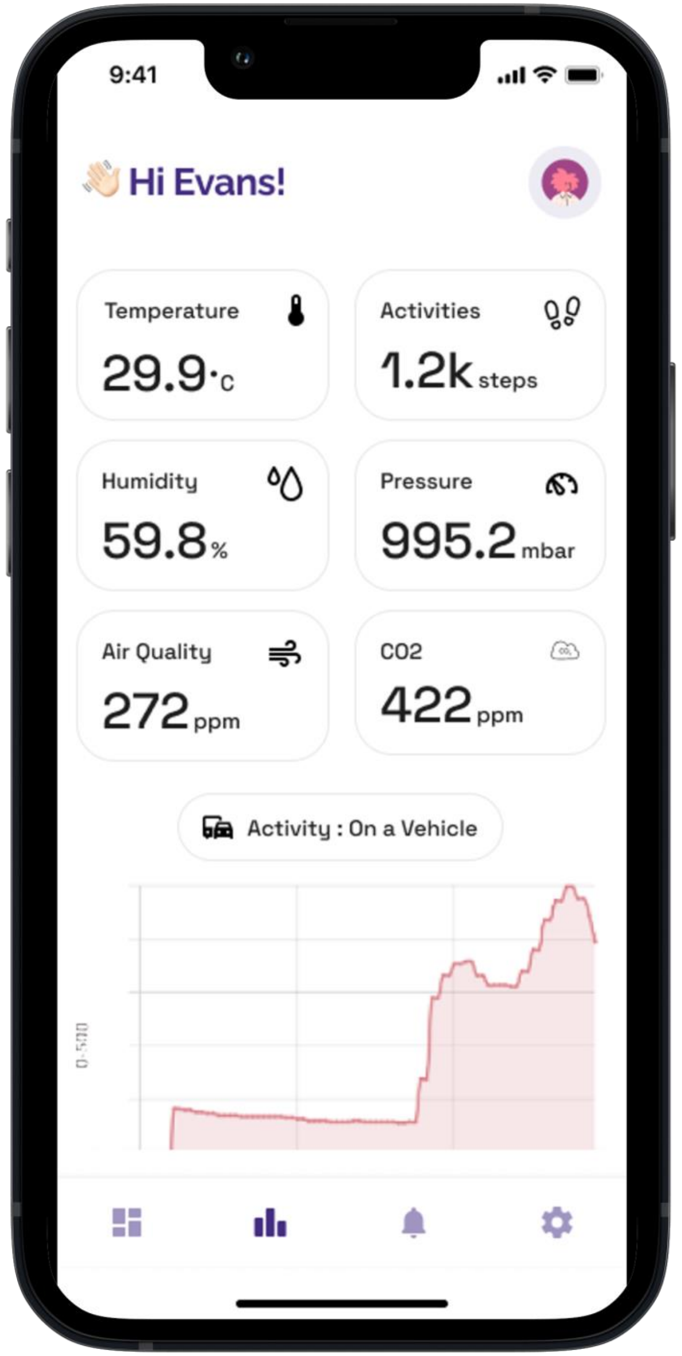
- Environmental impact on health tracking
- Exercise condition monitoring such as Walking, Running, Jumping, Sitting, etc.
- Indoor air quality alerts for gases such as Volatile Organic Compounds (VOCs), Volatile Sulfur Compounds (VSCs), Carbon Monoxide and Hydrogen in the ppb range.
- Weather-related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

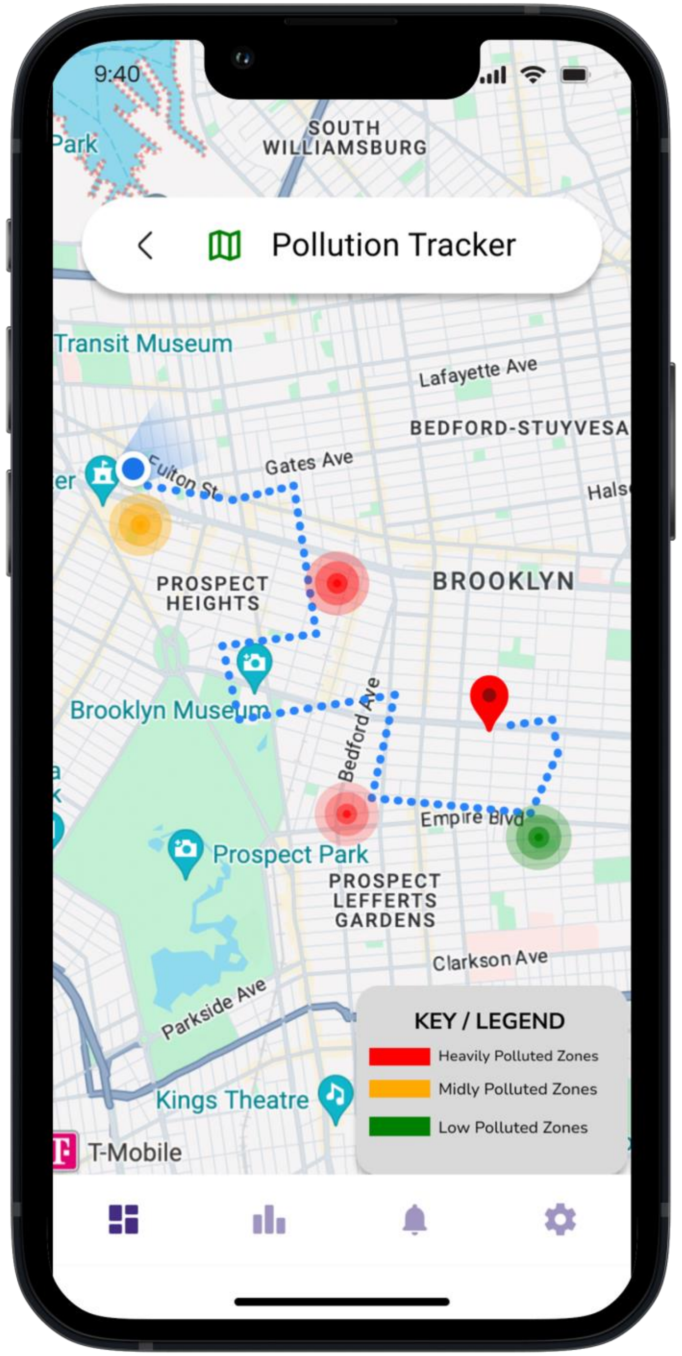
Outdoor Recreation

- 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)**

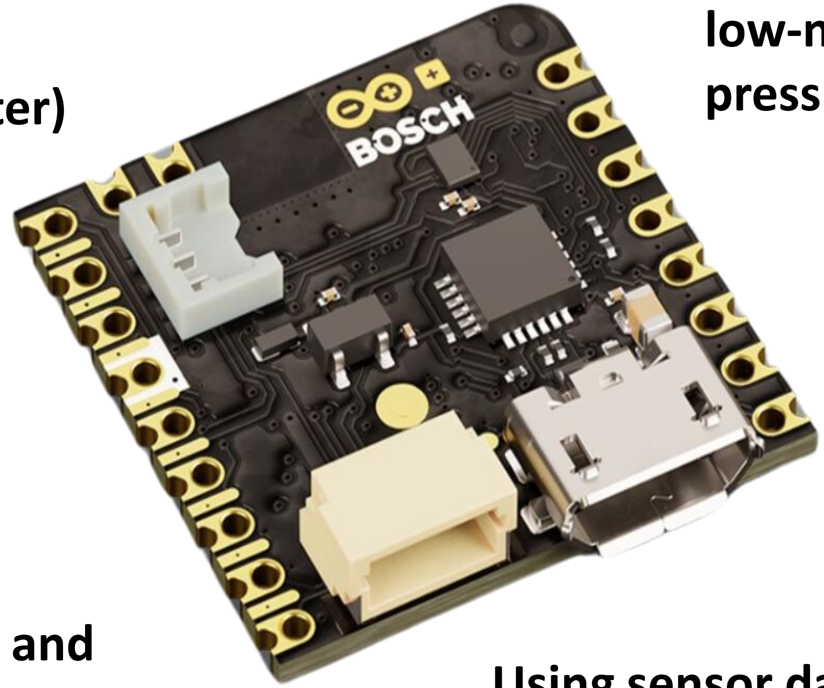
This cost is significantly lower than premium devices like the Apple Watch (~**GH₵15,000**).

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)
- React Native (Mobile App)
- TypeScript
- Tailwind CSS
- Redux (State management)

Backend Technologies

- Firebase
- Node JS
- .NET
- PostgreSQL

TECHNOLOGIES USED

Hosting Services

- Vercel/Render (Web Hosting)
- Render (Backend Hosting)
- Neon (Database Hosting)

Machine Learning & Analytics

- Quantization and pruning for real-time edge inference
- LSTM networks for fall detection
- Sensor data normalization (z-score).
- Time-series windowing for motion data.
- Pollution map & analytics using Mapbox

Authentication & Security

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

PROPOSED SYSTEM ARCHITECTURE

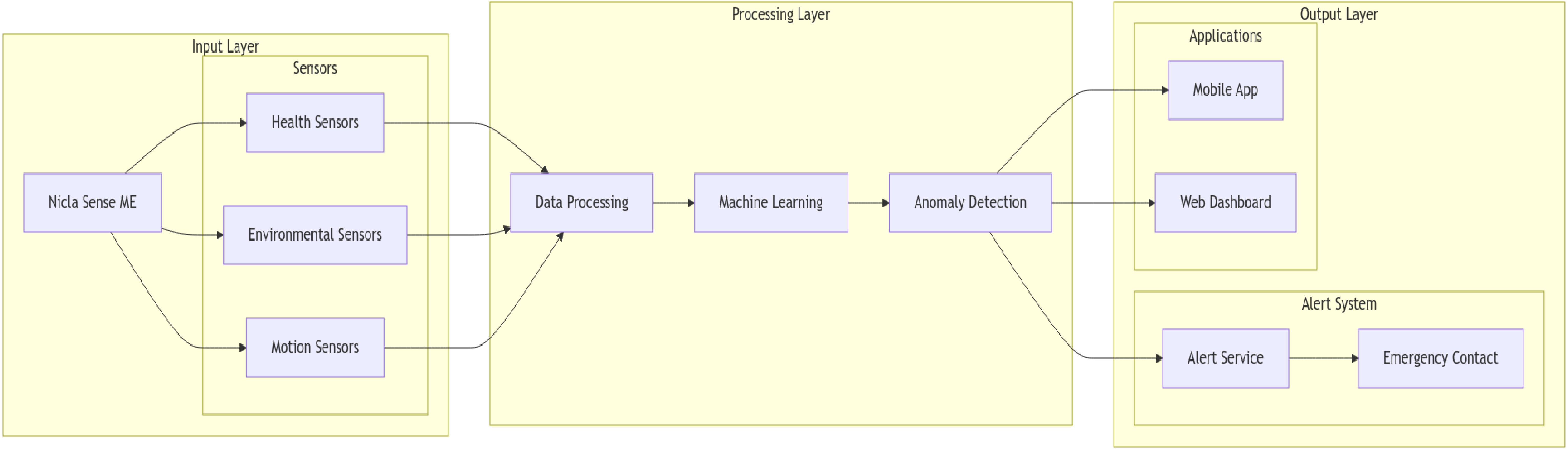


Figure 1: Proposed System Architecture

PROPOSED DATA FLOW DIAGRAM

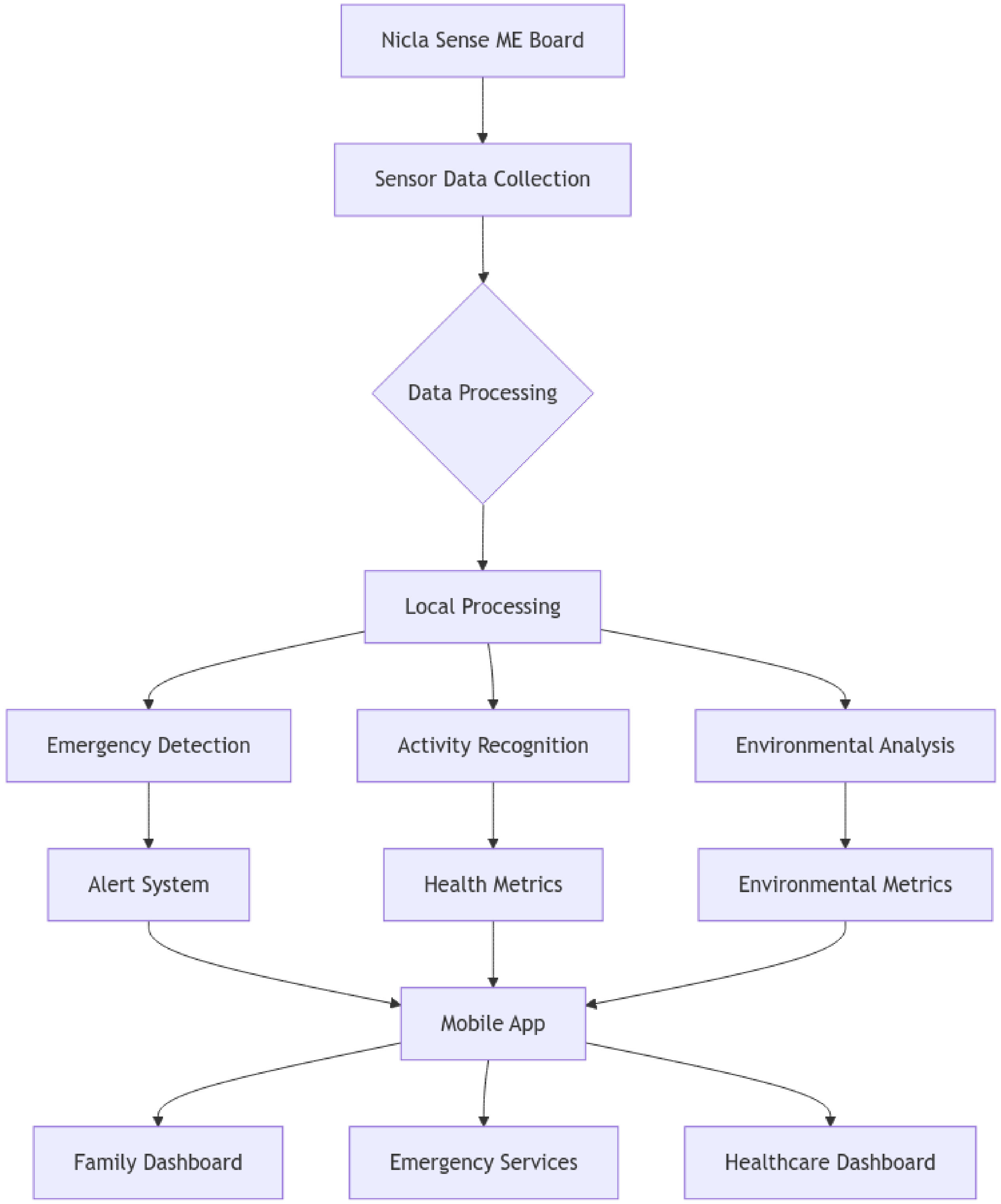


Figure 2: Proposed Data Flow Diagram

DATABASE SCHEMA RELATIONSHIPS

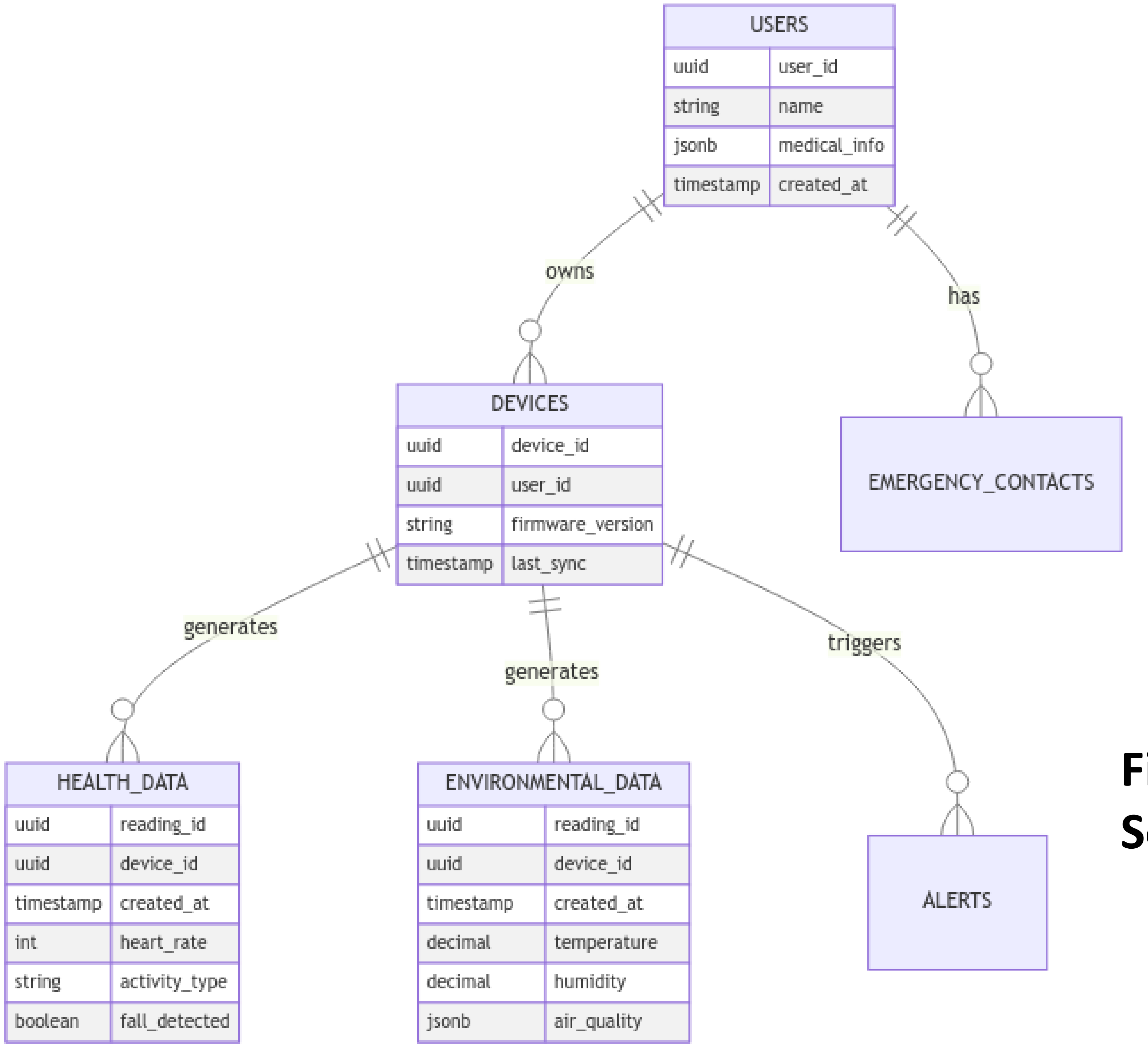


Figure 4: Database Schema Relationships

PICTORIAL VIEW OF PROPOSED SYSTEM OVERVIEW

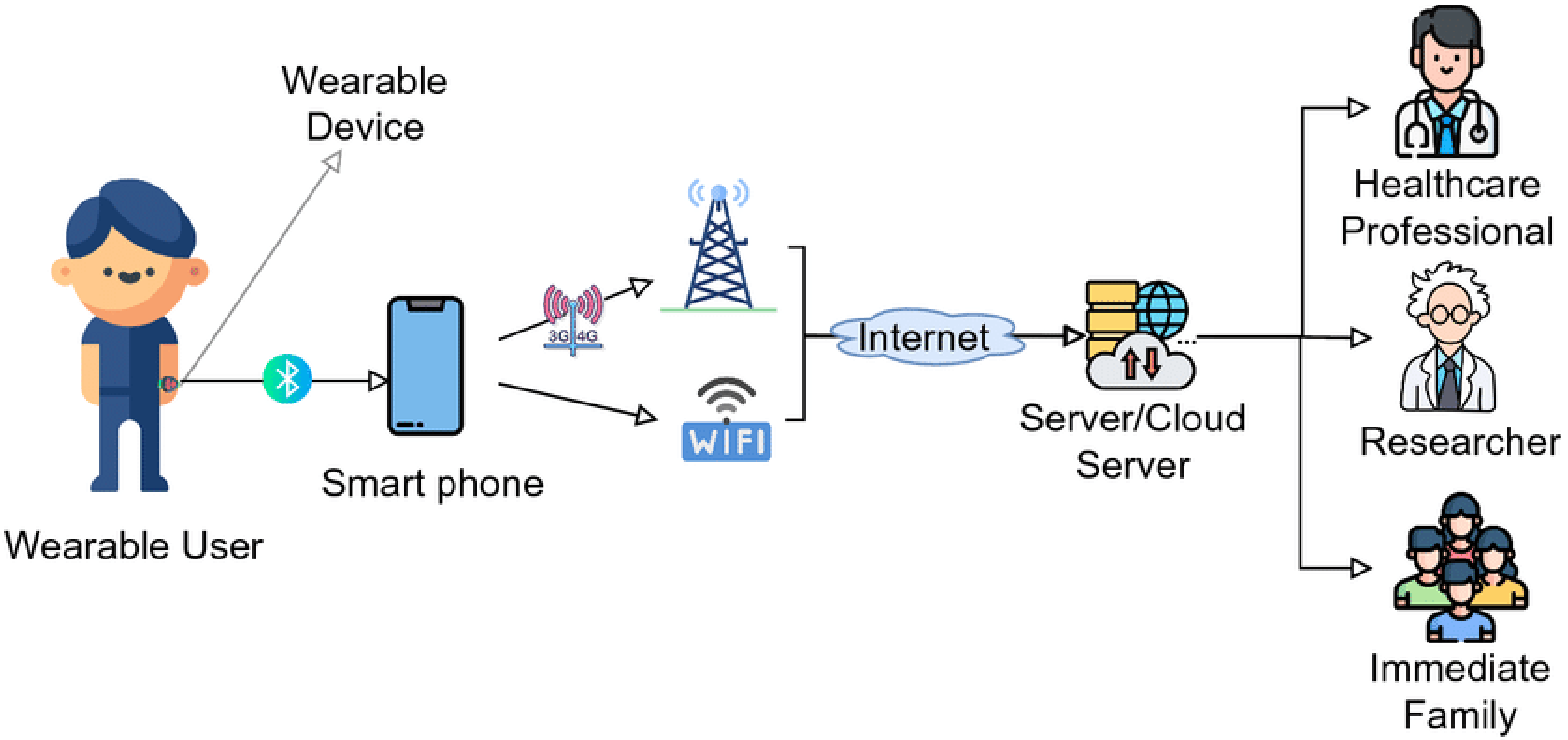


Figure 5: Pictorial view of proposed system overview – [6]

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

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THANK YOU!