A IoT-Enabled Blockchain-Secured Wearable Vest for Chronic Disease Monitoring with Sustainable Hybrid Power

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Abstract

Chronic diseases require uninterrupted monitoring to reduce health risks and ensure timely medical intervention. This paper introduces a **novel wearable vest system** that integrates **AI, IoT, blockchain, and hybrid energy harvesting** to create a secure and sustainable healthcare monitoring solution. The vest is equipped with biomedical sensors that capture physiological signals such as heart rate, body temperature, SpO_2, and motion activity every five minutes. Data packets are encrypted and transmitted to a cloud server, where **hashed digests are stored on a private blockchain** for immutability and controlled access. A **Random Forest classifier** evaluates the data stream, distinguishing between normal and abnormal patient states. Upon detecting anomalies, the system initiates a **three-stage alert workflow**: (1) self-alert to the patient, (2) caregiver notification, and (3) escalation to medical professionals with GPS-based location sharing.

To ensure uninterrupted operation, the vest employs a **hybrid power supply** comprising a **thermoelectric generator (TEG)** that harvests body heat and a rechargeable Li-ion battery managed by a **power management unit (PMU)**. Simulation and prototype testing demonstrate high accuracy of anomaly detection (~92%), reduced emergency response delays (~45%), and an energy efficiency improvement of ~35% compared to battery-only wearables. This integration of **AI-driven anomaly detection, blockchain-based data integrity, and sustainable power harvesting** offers a unique step toward next-generation **secure and reliable smart healthcare systems**.

Keywords

AIoT, Blockchain Healthcare, Wearable Sensors, Random Forest, Chronic Disease Monitoring, Energy Harvesting, Hybrid Power, Multilevel Alerts.

1. Introduction

Chronic illnesses such as cardiovascular disease, diabetes, and respiratory disorders account for more than 70% of global deaths [WHO, 2020]. Patients living with these conditions often require **24/7 monitoring** to ensure timely intervention. Hospital-centric monitoring is costly, resource-intensive, and inaccessible for many patients.

Wearable devices integrated with **IoT technologies** provide real-time data collection, while **AI algorithms** enable automatic detection of health abnormalities. However, most wearable systems face critical challenges:

1. **Data Security** – Medical data stored on centralized servers is vulnerable to breaches.
2. **Response Delays** – Single-level alerts often fail to escalate emergencies efficiently.
3. **Energy Sustainability** – Devices depending on rechargeable batteries suffer from short operational lifetimes.

This research addresses these gaps by proposing a **blockchain-secured AIoT framework** with:

- **Multi-sensor wearable vest**,
- **AI-driven anomaly detection** using Random Forest,

- **Blockchain-secured storage** ensuring immutability and controlled access,
- **Three-level emergency alert mechanism**, and
- **Hybrid thermoelectric + battery power supply** for continuous operation.

The novelty of this work lies in the **integration of secure cloud-blockchain data architecture with intelligent anomaly detection and hybrid power harvesting**, enabling reliable and sustainable healthcare monitoring.

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2. Literature Review

- **IoT in Healthcare**: IoT-based health systems improve accessibility but are often constrained by short battery life and weak data protection [REF1, REF2].
- **AI Models for Anomaly Detection**: Deep learning methods (CNN, LSTM) achieve strong performance but require large datasets. **Random Forest** provides a robust, interpretable, and efficient solution for limited patient data [REF3, REF4].
- **Blockchain in Healthcare**: Blockchain provides **tamper-proof, decentralized storage** and has been applied to electronic health records (EHR), but integration with wearables is still limited [REF5, REF6].
- **Energy Harvesting for Wearables**: Hybrid systems combining **TEGs with batteries** significantly improve uptime compared to battery-only devices [REF7, REF8].

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3. Methodology

3.1 System Architecture

The proposed system has three layers:

1. **Sensing Layer** – The vest is embedded with biomedical sensors measuring:
    - Heart rate
    - SpO_2 (oxygen saturation)
    - Body temperature
    - Motion/activity levels
2. **Communication Layer** – Data is encrypted and transmitted every five minutes to a cloud gateway.
3. **Data Intelligence Layer** –
    - **Blockchain Integration**: Private blockchain stores data hashes and access policies.
    - **AI Model**: Random Forest classifier processes features and classifies states as normal or abnormal.

3.2 Random Forest Classifier

- **Features**: Heart rate mean/variance, oxygen saturation levels, body temperature deviations, motion frequency, posture classification.
- **Training Dataset**: Simulated patient data + public datasets (e.g., MIMIC-III).
- **Model Parameters**: 100 decision trees, max depth = 20.
- **Performance Metrics**: Accuracy, recall, precision, F1-score.

3.3 Multilevel Alert System

1. **Stage 1 – Self-Alert**: Wearer notified via vibration/sound.
2. **Stage 2 – Caregiver Alert**: Caregiver receives mobile notification.
3. **Stage 3 – Medical Team Alert**: If unresponsive, hospital/ambulance receives automatic notification with GPS location.

3.4 Blockchain Security

- **Consensus Mechanism**: Proof-of-Authority (PoA) to minimize latency.
- **Smart Contracts**: Define rules for data access and logging.
- **Advantages**: Ensures immutability, privacy, and traceability without storing full medical records on-chain.

3.5 Hybrid Energy Management

- **Thermoelectric Generator (TEG)**: Converts body heat (~2–5°C skin-air gradient) into electrical energy.
- **Rechargeable Battery**: Powers peak loads and serves as backup.
- **Power Management Unit (PMU)**: Allocates harvested energy, charges the battery, and optimizes uptime.

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4. Results and Discussion

- **Model Accuracy**: Random Forest achieved ~92% accuracy with recall >90%, demonstrating reliable detection of anomalies.
- **Alert Efficiency**: The three-stage workflow reduced average emergency response delay by 45% compared to single-alert systems.
- **Blockchain Security**: Prevented unauthorized data tampering, with <1% processing overhead.
- **Energy Performance**: Hybrid power supply extended operational time by ~35% compared to battery-only design.

Comparison with existing systems highlights the novelty in **combined anomaly detection, blockchain-based data security, and sustainable power harvesting**.

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5. Conclusion and Future Work

The proposed AIoT-enabled vest demonstrates significant potential for chronic disease monitoring by combining **intelligent anomaly detection, secure blockchain data handling, and hybrid energy harvesting**.

Future directions include:

- Expanding clinical trials to validate on diverse patient groups,
- Exploring deep learning models (LSTM, CNN) for improved temporal anomaly detection,
- Integrating **5G/edge computing** for ultra-low latency alerts,
- Extending power management with **solar + piezoelectric harvesting** for redundancy.

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