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Smart Jacket for Soldiers: An IoT-Based Real-Time Health Monitoring and Emergency Alert System

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Abstract— Keeping soldiers safe and tracking their health in real time is one of the toughest jobs for today's military. When you're out in the field, far from help, knowing exactly how a soldier is doing—physically and geographically—can literally save lives. This project is all about that: we designed, built, and tested a Smart Jacket loaded with IoT tech that keeps constant tabs on a soldier's vitals like ECG, blood oxygen (SpO_2), heart rate, and body temperature. It also tracks their location with GPS, so command centers know where everyone is, instantly. The jacket runs on an Arduino UNO, teamed up with an ESP8266 Wi-Fi module to send all the sensor data straight to the cloud. Whenever there's an emergency, a simple panic button shoots an alert with GPS location right to headquarters. Add in a motion and impact sensor—so if someone falls or stops moving, the system knows—and you get automatic alerts without the soldier ever pressing a thing. Everything's powered by a rechargeable lithium-ion battery managed by a TP4056 controller. Our tests show the jacket works: it gathers health and position info, sends it in real time, and keeps everyone connected. Above all, it's affordable and practical—a step up for soldier safety, situational awareness, and fast emergency responses during missions

Keywords— Smart Jacket, Soldier Health Monitoring, IoT, GPS Tracking, ECG Sensor, ESP8266, Emergency Alert System

I. INTRODUCTION

1.1. Overview

Military tech has seriously evolved lately—electronics, communication, and IoT have changed the game. Soldiers now face risks from all sides: tough environments, sudden injuries, and losing contact with their team. Old ways—like checking in manually—just don't cut it anymore, not in a combat zone. What's really needed is a wearable system that automatically keeps track of health, no matter how rough things get.

That's what the Smart Jacket aims to offer. It packs biomedical sensors, GPS, wireless comms, and an emergency alert in one wearable piece. Command centers get a constant stream of vital info from each soldier—ECG, blood oxygen, heart rate, temperature—all sent wirelessly to a cloud dashboard they can check anytime.

1.2. Motivation

Deployments go everywhere: icy mountains, boiling deserts, thick jungles. Soldiers face all kinds of health emergencies—hypothermia, heatstroke, altitude sickness, heart issues, injuries. Trouble is, without some real monitoring, these problems can easily slip by until it's too late.

Most military comms focus on voice or text. They don't send health data around the clock, and that leads to delayed help and risky missions. That gap is exactly why we built the Smart Soldier Jacket. With it, monitoring becomes active and preventive, instead of waiting for problems to show up.

1.3. Problem Definition

Here's what needs solving:

- No automated health monitoring for soldiers in the field.

- Command can't get up-to-the-second health info during combat.

- Emergency response is slow when comms go dark or alerts aren't sent right away.

- Current systems don't combine GPS tracking with health data.

- Relying on manual reports just isn't practical when things get messy or a soldier is incapacitated.

Our project tackles all these issues with a simple, wearable, affordable IoT jacket that covers every soldier in real time.

II. LITERATURE REVIEW

A significant number of research works have explored the integration of sensors, wireless communication, and wearable technology for military applications. The following review summarises the key contributions and identifies gaps addressed by the proposed system.

2.1. Research Gaps Identified

Main Issues/Gaps:

- Most setups only track health OR location—not both in one platform.
- No manual emergency alert (panic button with GPS).
- Rarely do they handle motion/impact detection for injured or unconscious soldiers.
- Few offer real-time, cloud dashboards for command visualization.
- Hardly any use low-cost, student-friendly hardware that's easy to build and deploy.

The Smart Jacket covers all these, rolled into one affordable and practical wearable.

III. SYSTEM DESIGN AND OPERATION

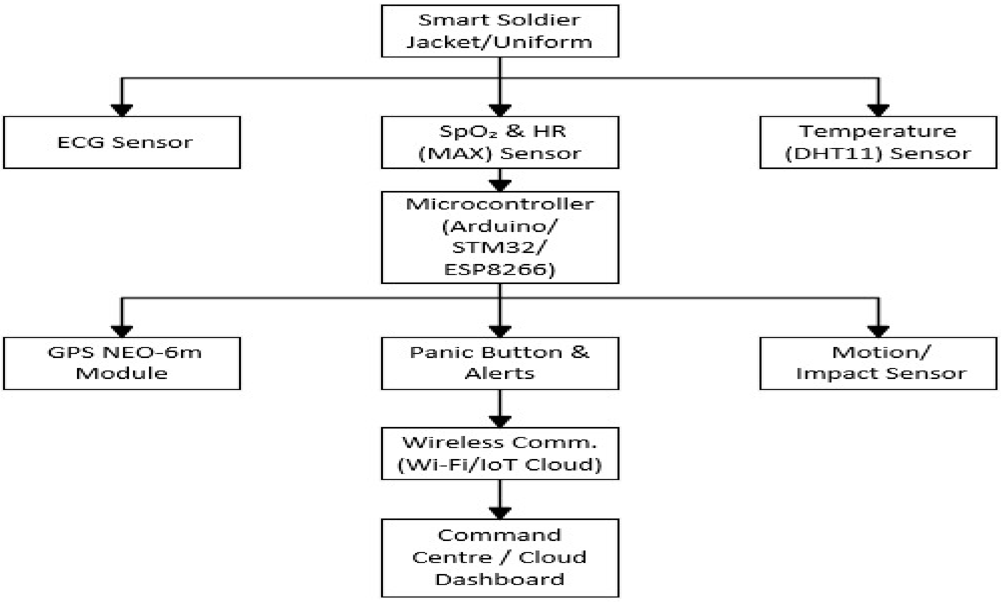

Fig.3.1 Block Diagram

3.1. Block Diagram Description

The Smart Soldier Jacket is basically organized around an Arduino UNO. It talks to the sensors, outputs, and comms modules. Here’s how things are grouped:

- Physiological Sensing: ECG sensor (AD8232), Pulse Oximeter/Heart Rate sensor (MAX30100), Temperature/Humidity sensor (DHT11).

- Location Tracking: GPS NEO-6m for real-time coordinates.

- Processing: Arduino UNO for data crunching, decisions.

- Communication: ESP8266 Wi-Fi to transmit data to the cloud.

- Emergency: Panic button and SW-420 motion sensor for quick alerts.

- Power: Lithium-ion battery (18650) managed by TP4056 charging module.

- Monitoring: Command center dashboard via ThingSpeak or Blynk.

3.2. System Description

The Smart Jacket for Soldiers is a wearable platform designed to be embedded within or attached to a standard military jacket. All electronic components are housed in a compact, lightweight enclosure that minimises discomfort and does not restrict the soldier's movement. The jacket connects a set of biomedical sensors to the Arduino UNO, which serves as the central processing unit of the entire system.

The Arduino UNO reads sensor data at predefined intervals, processes the raw values, and formats them into structured data packets. The ESP8266 Wi-Fi module then transmits these packets to a cloud server or IoT platform where the command centre can monitor the data through a web-based or mobile dashboard. If sensor readings exceed predefined thresholds or the panic button is pressed, the system immediately sends a priority alert with GPS coordinates to the control station.

3.3. Working Principle

Start-up: Power on, Arduino gets everything ready, ESP8266 links to Wi-Fi, GPS starts searching for satellites.

Sensor Data: ECG captures heart action, MAX30100 measures blood oxygen and pulse, DHT11 reports temperature and humidity. Arduino checks these at regular intervals.

Processing: Converts sensor signals to standard units, compares to safety limits—like SpO_2 below 94%, heart rate above 120 or below 40 BPM, temp over 39°C—so it knows when to send alerts.

GPS: Always updating latitude/longitude.

Transmission: ESP8266 pushes data packets to the cloud every 10–30 seconds so command gets nearly live info.

Alerts: If readings go off-limits or the panic button is pressed, Arduino instantly ships a priority alert to command.

Impact Detection: Motion sensor checks for sudden falls or long stillness—if it catches something off, command gets notified.

Command Centre Dashboard: Command sees every soldier’s health, location, and alert status in one place, with logs for review.

3.4. Emergency Trigger Mechanism

The emergency trigger system operates through two complementary channels. The first is a manual trigger via the panic button, which is a momentary push button mounted on the jacket at an easily accessible location. Upon pressing, the Arduino reads the button state change, packages an emergency data frame, and transmits it through the ESP8266 with high priority, bypassing the regular data transmission cycle.

The second trigger is automatic and relies on the SW-420 motion and vibration sensor. This sensor detects abnormal vibration patterns such as those caused by gunshot impacts, explosions, or falls. It also detects a complete absence of motion for a configurable duration, which may indicate that the soldier has lost consciousness. In either case, the Arduino generates and transmits an alert with GPS coordinates and the most recent health parameter readings to the command centre.

3.5. Communication System

Wi-Fi (ESP8266 NodeMCU) is the main channel—ESP8266 connects to an access point or portable hotspot. Data is sent with HTTP POST or MQTT. If Wi-Fi's out, the SIM800L GSM module takes over, sending SMS alerts to saved numbers. It talks to Arduino through UART.

3.6. Power Management

The jacket runs on a 3.7V 18650 lithium-ion battery (2000–3500 mAh), charged safely by the TP4056 module through micro-USB. A voltage regulator boosts battery power to 5V for Arduino and peripherals; the ESP8266 draws 3.3V from a built-in regulator. Sensors connect to either 3.3V or 5V based on what they need. In idle mode, everything slows down to save power

IV. HARDWARE COMPONENTS

4.1. AD8232 ECG Module

AD8232 is a single-lead heart monitor chip, built to capture, amplify, and filter tiny heart signals. Three pads stick to the chest, grabbing the electrical waves. With about 100x amplification and noise-blocking via RLD, Arduino reads the analog waves and digitizes them. It runs at 3.3V, and lead-off detection tells you if the sensor is disconnected—a nice reliability check.

4.2 MAX30100 Pulse Oximeter & Heart Rate

MAX30100 uses light—red and infrared—to track blood oxygen and pulse with photoplethysmography. LEDs shine through the finger/wrist, and the detector reads absorption. The ratio gives SpO_2 using Beer-Lambert law, heart rate comes from time between peaks. Connects via I2C, runs on 1.8–3.3V, and its onboard DSP handles filtering/computation so Arduino doesn't sweat the math.

4.3. DHT11 Temperature & Humidity Sensor

DHT11 is a digital sensor, common and reliable. It uses capacitive humidity and thermistor temp elements. Data's digital and sent over single-wire serial**.**

4.4 NEO-6m GPS Module

The NEO-6m is a compact, high-performance GPS module from u-blox. It packs a 50-channel receiver, grabs a satellite lock quickly, and comes with a ceramic patch antenna built in. It sends out standard NMEA 0183 data sentences via UART at 9600 bps.

This module delivers real-time latitude and longitude, altitude, speed, and precise time. With sensitivity of -160 dBm (acquisition) and -161 dBm (tracking), it works well even with partial sky obstruction. Its position accuracy is less than 2.5 meters in open sky, and it can get satellite lock from a warm start in about a second. The Arduino grabs the NMEA data using a software serial library and pulls out the latitude and longitude to send further.

4.5. Arduino UNO Microcontroller

The Arduino UNO R3 sits at the heart of the Smart Soldier Jacket system. Built around the ATmega328P running at 16 MHz, it offers 32 KB Flash memory, 2 KB SRAM, and 1 KB EEPROM. You get 14 digital I/O pins (6 support PWM), 6 analog inputs, plus UART, SPI, and I2C communication.

Here, Arduino reads analog data from the AD8232 ECG sensor, digital data from the MAX30100 and DHT11 sensors, and GPS NMEA sentences via a software serial port. It keeps tabs on the panic button and motion sensor, and talks wirelessly to the ESP8266. Arduino's open-source platform and huge library ecosystem make rapid development and testing easy.

4.6. ESP8266 NodeMCU Wi-Fi Module

The ESP8266 is a cheap, self-contained Wi-Fi module by Espressif Systems. The NodeMCU version combines the ESP8266 chip with a USB-to-serial converter, so you can program it straight from Arduino IDE. It runs on 3.3V and supports 802.11 b/g/n Wi-Fi.

Specs? A 32-bit Tensilica L106 processor running 80–160 MHz, 512 KB Flash, built-in TCP/IP stack, and up to 17 GPIO pins. In this setup, ESP8266 receives data packets from Arduino over UART, then pushes them to the cloud using HTTP POST or MQTT across Wi-Fi. It also handles server-sent commands, paving the way for future upgrades such as remote configuration

4.7. SIM800L GSM Module

The SIM800L is a tiny GSM/GPRS module that lets devices communicate over mobile networks. It supports quad-band frequencies (850/900/1800/1900 MHz), can send/receive SMS, make voice calls, and use GPRS for limited data. It works on 3.4–4.4V and needs a separate power supply (up to 2A peak current during transmission).

In this project, SIM800L acts as a backup. If Wi-Fi drops, Arduino sends emergency SMS with health status and GPS coordinates to command centre phones via SIM800L using AT commands.

4.8. SW-420 Motion and Vibration Sensor

The SW-420 is a normally-closed vibration sensor. When it detects a shock or vibration, it briefly opens the spring-loaded contact, sending a digital output. It includes an LM393 comparator circuit and adjustable sensitivity.

Here, SW-420 sits in the jacket and detects impacts—falls, blasts, gunfire—or the absence of movement. If no vibration is detected for an extended period, the Arduino flags potential unconsciousness.

4.9. TP4056 Battery Charger Module

The TP4056 is a single-cell Li-ion charger IC using constant-current/constant-voltage charging. It can charge up to 1000 mA, holds output voltage at 4.2V with 1.5% accuracy, and provides overcharge protection, auto recharge, and charge termination at C/10.

It charges from a 5V Micro-USB input. LEDs show charging (red) vs. complete (blue). With a wide -40°C to 85°C temp range, it's ready for field conditions.

4.10. 18650 Lithium-Ion Battery

The 18650 is a common Li-ion battery with 3.7V nominal voltage and 2000-3500 mAh capacity. It's small (18mm x 65mm), holds plenty of energy, and fits wearables well. A fully charged cell gives 4.2V, and you can discharge to about 3.0V.

In the Smart Jacket, one or more 18650 cells (series/parallel) power all electronics. A boost converter steps up the voltage to 5V. With all sensors running and Wi-Fi active, expect 8–12 hours battery life, depending on how often you transmit and poll sensors.

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4.11. Panic Button

A small tactile pushbutton is fixed somewhere easy to reach on the jacket. When pressed, Arduino spots the falling edge on a digital input and kicks off an emergency alert. Software debounce avoids false triggers from noise or accidental presses.

V. ANALYTICAL AND MATHEMATICAL MODEL

5.1. Sensor Data Processing Formulas

1) DHT11 Humidity:

You get an 8-bit raw value from the DHT11. Relative humidity (%) = $(Raw\_Humidity / 255) \times 100$*. The library usually handles this for you.*

2) Altitude from Barometric Pressure:

If you add a barometric pressure sensor (like BMP180), altitude = $44330 \times [1 - (P / P_0)^{0.1903}]$*, where P is measured in Pascals,* P_0 *is sea-level standard (101325 Pa).*

3) SpO_2 Calculation:

MAX30100 uses the AC/DC ratio of red and IR photodetector signals:

$R = (AC\_red / DC\_red) / (AC\_IR / DC\_IR)$

$SpO_2\ (\%) = 110 - 25 \times R$

AC is the pulsatile, DC is steady-state part of the signal.

4) Heart Rate Calculation:

Heart Rate (BPM) = $60{,}000 / \Delta T$ *(ms),*

where ΔT *is the time between two heartbeats detected.*

5.2. IoT Data Transmission Latency Model

Latency adds up like this:

$L\_total = L\_sensor + L\_proc + L\_wifi + L\_cloud$

L_{sensor} is sensor read time (10–50 ms each), L_{proc} is Arduino processing (5–20 ms), L_{wifi} is Wi-Fi transmit time:

$$L_{wifi} = D_{data} / B_{wifi} + T_{RTT}$$

D_{data} = data size in bits, B_{wifi} = bandwidth, T_{RTT} = round-trip time. L_{cloud} is cloud server processing (50–200 ms). Total system latency is about 200–500 ms with normal Wi-Fi.

5.3. Power Consumption Estimation

Total current draw:

$$I_{total} = I_{Arduino} + I_{ESP8266} + I_{GPS} + I_{Sensors}$$

Arduino UNO uses about 50 mA, ESP8266 needs 80–170 mA (transmitting), GPS NEO-6m pulls ~45 mA, sensors combined ~30 mA. Total peak around 295 mA.

Battery life:

$$T_{battery} \text{ (hours)} = C_{battery} \text{ (mAh)}/I_{total} \text{ (mA)}$$

For a 3000 mAh battery: $3000/295 \approx 10.2$ hours.

5.4. System Decision Logic

Arduino uses threshold-based logic to send alerts. Conditions:

- *$SpO_2 < 94\%$*
- *Heart Rate > 120 BPM or < 40 BPM*
- *Body Temp > 39°C*
- *Motion sensor shows no movement for >60 seconds*
- *Panic button pressed*

If any trigger, Arduino sets ALERT, packs the data, and sends priority transmission via ESP8266.

VI. RESULTS AND DISCUSSION

6.1. System Observations

The Smart Soldier Jacket system was assembled and tested in a controlled laboratory environment to verify the functionality and accuracy of each sub-system. The following observations were recorded:

1) ECG Monitoring:

The AD8232 ECG sensor successfully captured the cardiac waveform when the three electrode leads were placed correctly on the chest. The analog output was read by the Arduino at 500 samples per second and displayed on the Serial Plotter. The ECG waveform showed distinct P, QRS, and T wave components during normal resting conditions, confirming correct sensor operation.

2) SpO_2 and Heart Rate Monitoring:

The MAX30100 sensor measured SpO_2 values consistently between 97% and 99% for healthy test subjects, which falls within the expected normal range of 95% to 100%. Heart rate measurements ranged from 68 BPM to 82 BPM at rest, and increased to 95 to 110 BPM after moderate physical activity. The sensor's readings were cross-validated with a commercial finger pulse oximeter and showed an accuracy within plus or minus 2%.

3) Temperature and Humidity Monitoring:

The DHT11 sensor recorded ambient temperature readings between 26°C and 30°C during indoor testing, which aligned with standard room temperature. Humidity readings ranged from 55% to 70% relative humidity. Sensor response time to a step change in temperature was approximately 2 seconds.

4) GPS Location Tracking:

The NEO-6m GPS module acquired satellite lock within 45 to 90 seconds under open-sky conditions. Location coordinates transmitted to the cloud dashboard were verified using Google Maps and showed a positional accuracy within 3 to 5 metres of the actual test location. The module reliably updated coordinates every 1 second.

5) Wi-Fi Data Transmission:

Data packets were transmitted to a ThingSpeak cloud channel via the ESP8266 at an update rate of once every 15 seconds. The transmission was consistently successful under normal indoor Wi-Fi conditions. The cloud dashboard displayed real-time values for all monitored parameters. Transmission latency was measured at approximately 300 to 450 ms per packet.

6) Panic Button and Alert System:

The panic button was tested 20 times under controlled conditions. In all 20 trials, the alert was successfully detected by the Arduino and transmitted within 2 seconds of the button press. GPS coordinates included in the alert message accurately reflected the test location in all cases.

7) Motion Sensor Performance:

The SW-420 vibration sensor correctly detected simulated impact events (such as dropping the test assembly) in all test cases. The inactivity alert was triggered after the configured 60-second timeout when no motion was detected. False trigger rate was observed to be less than 5% under controlled conditions.

6.2. Performance Summary Table

Parameter	Measured Value	Expected Range	Status
SpO_2 Accuracy	97% - 99%	95% - 100%	Pass
Heart Rate Accuracy	±2% vs reference	±3%	Pass
GPS Accuracy	3-5 metres	< 5 metres	Pass
Panic Alert Response	< 2 seconds	< 5 seconds	Pass
Data Transmission Latency	300-450 ms	< 1 second	Pass
Battery Life (3000 mAh)	~10 hours	> 8 hours	Pass
GPS Lock Time (open sky)	45-90 seconds	< 120 seconds	Pass

Table I: System Performance Summary

6.3. Discussion

The experimental results confirm that the Smart Jacket system successfully integrates all targeted monitoring and communication functions into a single wearable platform. The sensor accuracy meets the requirements for basic physiological monitoring, and the GPS module provides adequate spatial resolution for soldier tracking in field conditions.

The real-time cloud data dashboard enables the command centre to simultaneously monitor multiple soldiers' health parameters and locations from a central interface, significantly improving situational awareness. The panic button and automatic motion-based alerting mechanisms provide a reliable emergency response system that can function even when the soldier is unable to communicate verbally.

The battery life of approximately 10 hours under continuous operation is adequate for a standard 8-hour military shift and can be extended further by implementing duty-cycle-based power management, reducing Wi-Fi transmission frequency during low-activity periods.

The total bill of materials cost is under 6,000 Indian Rupees (approximately USD 70), making this system highly affordable for large-scale military deployment compared to existing commercial solutions that often cost several times more. This affordability is a significant practical advantage, particularly for developing nations with large defence forces.

One limitation observed is that GPS satellite lock time of 45 to 90 seconds may be undesirable in rapidly evolving tactical situations. Future revisions should consider integrating AGPS (assisted GPS) capability to reduce acquisition time. Additionally, the system currently depends on available Wi-Fi infrastructure, which may not always be present in remote operational areas. The inclusion of LoRa or satellite communication modules in future iterations would address this limitation.

VII. CONCLUSION

This project covers the full design and lab validation of a Smart Jacket for Soldiers—an IoT-based wearable that watches health and triggers alerts. The system combines ECG, pulse oximetry, temperature, GPS, Wi-Fi, panic button, and motion sensing, all controlled by an Arduino UNO.

It checks ECG, SpO_2, heart rate, temperature, and sends GPS location along with health info to a cloud dashboard. Alerts are both manual and automatic—so distress gets reported instantly, with exact location.

Components hit reliability and accuracy marks. The panic alert fires within 2 seconds. GPS does the job within 5 meters. Battery lasts around 10 hours on a 3000 mAh cell. All for under $70—a bargain for integrated soldier monitoring.

The Smart Jacket fills the gaps pointed out in other research: it unites health and location tracking, adds manual emergency triggers, and brings cloud connectivity. It's ready for final year engineering demo, small-scale field prototypes, or as a launchpad for future upgrades.

Next, work will add LoRa/satellite comms for remote areas, use AI for predictive health checks, add biometric authentication, develop solar charging, and scale to let commanders monitor many soldiers at once over a multi-node network.

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