

# Multi-Sensor IoT Platform for Autonomous Elder Care and Security Management

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**Abstract:** Elderly individuals living alone face significant challenges related to continuous health monitoring, security, and timely emergency response. This paper presents a comprehensive IoT-enabled Smart Elder Care Service that integrates physiological monitoring (heart rate and ambient/body temperature), safety monitoring (PIR motion and magnetic door sensors), and resilient emergency notification mechanisms (MQTT/ThingSpeak + GSM SIM900A fallback). The system is designed around a NodeMCU ESP8266 microcontroller, and supports local (buzzer/LED) and remote (SMS/call, cloud dashboard) alert channels. We provide design rationale, hardware/software implementation details, block and flow diagrams, pseudocode for alert logic, a security and privacy discussion, performance evaluation methodology, and an appendix with an Arduino/ESP8266 sketch template. The architecture is modular, low-cost, and suitable for scaled deployments in assisted-living institutions and home-care scenarios.

**Keywords:** IoT, Elder Care, Health Monitoring, Safety Sys- Tem, Emergency Response, MQTT, GSM, ESP8266, ThingSpeak.

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## I. INTRODUCTION

The rapid aging of the global population has made elderly care an increasingly important societal challenge. According to multiple demographic studies, the proportion of elderly people (age  $\geq$  60) is rising worldwide, leading to increased demand for technologies that enable independent living while assuring safety and timely medical assistance. Traditional caregiving methods often rely on on-site personnel or wearables that require user compliance; both present cost, logistic, and re- liability challenges.

Internet of Things (IoT) technologies — encompassing low- cost sensors, networked microcontrollers, and cloud visualization platforms — create opportunities to monitor health and home-safety in real-time. However, many existing systems focus narrowly on either health (e.g., wearable heart-rate trackers) or home security (e.g., alarm systems), and few integrate a resilient, dual-path alerting strategy (internet + cellular) required for reliable emergency response.

➤ *This Work Presents a Fully Integrated, Low-Cost IoT Elder Care System that:*

- Continuously monitors vital signals: heart rate (pulse

sensor) and ambient/body temperature (DHT11).

- Supervises home safety via PIR motion and magnetic door sensors.
- Provides local immediate alerts (buzzer, LED), cloud visualization (ThingSpeak via MQTT), and GSM-based SMS/call fallback (SIM900A) for resilience.
- Uses modular, open hardware/software so it can be extended with fall detection, ML-based anomaly detection, or wearable integration.

The remainder of the paper is organized as follows: Section II reviews related literature. Section III details the shortcomings of existing solutions. Section IV describes our proposed system with block diagrams and flowcharts. Section V explains implementation details. Section VI presents evaluation methodology and results. Section VII discusses privacy, security, advantages and drawbacks. Section VIII outlines future work and conclusions. An appendix includes an Arduino/ESP8266 sketch outline and configuration note.

## II. LITERATURE REVIEW

To position our contribution, we reviewed prior work across three related streams: IoT health monitoring, smart-

home safety systems, and integrated elder-care solutions. Below we summarize representative studies and identify gaps.

#### ➤ *IoT-Based Health Monitoring*

Riazul Islam et al. provided a comprehensive survey of IoT in healthcare, reporting that low-power sensors, cloud platforms, and mobile integrations are key enabling technologies [1]. More recent wearable systems (e.g., HOT Watch) demonstrate the potential for continuous physiologic monitoring but suffer from compliance and battery constraints [3].

#### ➤ *Smart-Home Safety Systems*

Numerous works have focused on using ambient sensors (PIR, door sensors, pressure mats) for safety and intrusion detection [2]. Most commercial home security solutions are proprietary and expensive, making them less accessible for elderly care in resource-constrained settings.

#### ➤ *Integrated Elder-Care Architectures*

Recent research emphasizes integrated solutions combining physiological monitoring with home-based sensors and emergency response. Clifton et al. explored personalized e-health monitoring using probabilistic models for personalization [4]. However, many academic prototypes lack cellular failover, reducing real-world resilience.

#### ➤ *Gaps and Our Focus*

From the literature, recurring limitations include: lack of integration across health and safety, reliance on internet-only paths for alerts, lack of low-cost and scalable designs, and minimal discussion of privacy/security implications. Our system addresses these by combining multiple sensing modalities, using dual-path notification (MQTT + GSM), and adopting modular hardware to keep costs low.

### III. EXISTING SYSTEM

#### ➤ *Existing Elder-Care Solutions Can be Grouped as:*

- *Manual Caregiving:*

Human caregivers visit homes or live with the elderly. Pros: human judgement. Cons: cost and availability.

- *Wearable-Based Systems:*

Wristbands or pendant devices that track vitals and may send alerts. Pros: accurate; Cons: require compliance, charge cycles, may be removed.

- *Standalone Alarm Systems:*

Panic buttons or property security systems. Pros: immediate local alerts; Cons: do not track health parameters.

- *Cloud-Only IoT Solutions:*

Systems that upload sensor data but rely solely on IP connectivity. Pros: centralized monitoring; Cons: fail during internet outages.

The key limitations are user compliance (wearables), single-functionality (standalone systems), and lack of

communications resilience (cloud-only systems). Table ?? earlier contrasted these with our proposed integrated approach.

### IV. PROPOSED SYSTEM

This section provides in-depth design details and rationale.

#### ➤ *Design Goals*

- **Reliability:** Dual-path notification ensures messages reach caregivers even during ISP outages.
- **Simplicity:** Minimize user interaction; provide passive ambient sensing plus a manual panic button.
- **Cost-effectiveness:** Use widely available, low-cost components to enable scaled deployments.
- **Privacy-aware:** Sensitive data stored with minimal retention and access controls.

#### ➤ *Architecture Overview*

Figure 1 (again in a double-column formatted figure) shows the high-level system. Sensors feed into NodeMCU ESP8266; NodeMCU publishes to an MQTT broker (which then feeds ThingSpeak dashboards) and also interfaces with a SIM900A module for GSM fallback. Local buzzer/LED provides immediate alarm.

#### ➤ *Alerting Policy and Priority*

Alerts are classified into:

- **Critical:** Heart rate beyond critical thresholds (too low or too high), manual panic button pressed — immediate local alert and SMS/call to caregiver, persistent until ACKed.
- **Warning:** Slight deviations in vitals or suspicious motion during night hours — publish to MQTT and notify caregiver via dashboard and optionally SMS.
- **Info:** Regular telemetry updates for monitoring/trend purposes.

### V. ALERTING ALGORITHM AND PSEUDOCODE

We provide a concise pseudocode for the embedded logic running on the NodeMCU. The algorithm uses debouncing, moving-average filtering for heart rate, and prioritized alerting.

**Algorithm 1** Embedded Alert Logic (outline)

```

1: Initialize sensors, connect Wi-Fi, MQTT, SIM900A
2: while true do
3:   hr ← ReadPulseSensor()
4:   temp, hum ← ReadDHT11()
5:   pirState ← ReadPIR()
6:   doorState ← ReadDoor()
7:   FilteredHR ← MovingAverage(hr)
8:   if PanicButtonPressed() == true then
9:     TriggerLocalAlert()
10:    SendMQTTAlert("panic", details)
11:    SendGSMAlert("panic", caregiverNumber)
12:   end if
13:   if FilteredHR > HR-HIGH-THRESHOLD or FilteredHR < HR-LOW-THRESHOLD then
14:     TriggerLocalAlert()
15:     SendMQTTAlert("critical_vitals", details)
16:     if InternetAvailable() == false then
17:       SendGSMAlert("critical_vitals", caregiverNumber)
18:     end if
19:   else if pirState == TRUE and NightTime() then
20:     SendMQTTAlert("possible_intrusion", details)
21:   end if
22:   PublishTelemetry() ▷ temperature, hr, motion, door
23:   Sleep(SAMPLE_INTERVAL)
24: end while
    
```

**VI. SYSTEM DESIGN AND IMPLEMENTATION**

This section describes the hardware wiring, firmware architecture, MQTT configuration, and cloud dashboard setup.

➤ *Hardware Wiring and Interfaces*

• *Key Wiring Notes:*

- ✓ Pulse sensor to NodeMCU ADC (A0) with proper voltage divider if needed.
- ✓ DHT11 to a digital GPIO with pull-up.

Table 1 Representative Prior Works — Summary

| Author / Year                           | Type            | Technologies                        | Limitations                                     |
|---|-----------------|-------------------------------------|---|
| Riazul Islam et al. (2015) [1]          | Survey          | IoT platforms, sensors, cloud       | Broad survey; few practical prototypes          |
| HOT Watch (Madavarapu et al., 2024) [3] | Wearable        | Wearable sensors, BLE, cloud        | Compliance/battery constraints                  |
| Skubic et al. (2015) [2]                | In-home sensing | Motion sensors, pattern recognition | Does not include telephony fallback             |
| Clifton et al. (2013) [4]               | ML in e-health  | Gaussian processes, wearables       | Complex personalization; high computation needs |

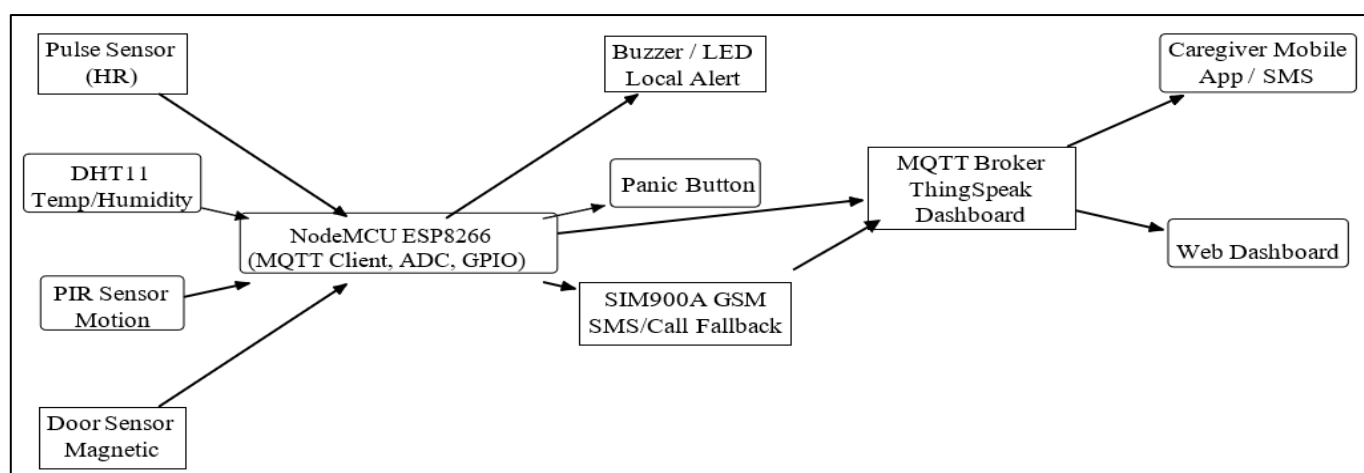


Fig 1 System Block Diagram: Sensors to MCU, Local Alerts, Cloud and GSM Fallback.

- ✓ PIR and door sensors to digital GPIOs with debouncing logic in software.
- ✓ SIM900A to NodeMCU via SoftwareSerial or TTL serial with appropriate voltage shifting (SIM900A usually needs 5V; ensure proper power supply).
- ✓ Buzzer/LED to GPIO via transistor drivers if necessary.

➤ *Firmware Architecture*

Firmware components:

- Sensor Drivers: Read and low-pass filter raw sensor values.

- Communication Module: Handles Wi-Fi, MQTT publishes/subscribes, and SIM900A AT command sequences.
- Alert Manager: Maintains alert state machine, ensures duplicate alerts are rate-limited.
- Power Manager: Optional, for battery-backed systems (sleep/wake policies).

➤ *MQTT and ThingSpeak Setup*

We use an MQTT broker (public or private) and

ThingSpeak for visualization:

- Publish telemetry to topics like ‘eldercare/id/vitals/heart’.
- Use retained messages for last-known-state of critical topics.
- Configure ThingSpeak private channels with write API keys to accept MQTT TTL or via the MQTT bridge (ThingSpeak supports API keys).

Table 2 Hardware Specification and Estimated Cost (in- Dicative)

| Component            | Specification                  | Estimated Cost (INR) |
|----------------------|--------------------------------|----------------------|
| NodeMCU ESP8266      | 80 MHz, Wi-Fi, 4 MB flash      | 250–400              |
| SIM900A              | GSM/GPRS module                | 600–900              |
| Pulse Sensor         | Optical pulse sensor (analog)  | 150–300              |
| DHT11                | Temp/Humidity sensor           | 50–100               |
| PIR Sensor           | Passive infrared motion sensor | 100–200              |
| Magnetic Door Switch | Reed switch                    | 30–80                |
| Buzzer, LEDs, Misc   | Drivers, resistors, wires      | 200–400              |
| Power Supply         | 5V regulator / battery         | 300–800              |
| Total (approx.)      |                                | 1600–3180            |

**VII. HARDWARE & SOFTWARE SPECIFICATIONS**

A detailed hardware and software specifications table is given below.

➤ *Energy and Power Considerations*

Continuous monitoring requires careful power budgeting. For mains-powered home installations, this is trivial. For battery-assisted deployments, implement deep-sleep cycles and event-driven wake-ups; for example: sample vital signs every 10 seconds and enter light sleep in between, or use PIR triggers to increase sampling when activity is detected.

**VIII. EVALUATION METHODOLOGY**

To evaluate the system we propose metrics and testbeds:

- Latency: Time from event detection to local alert, MQTT publish, and SMS delivery.
- Accuracy: Heart rate compared with a reference pulse oximeter (MAE, RMSE).
- Reliability: Percentage of successful alerts delivered during Internet outages (GSM fallback effectiveness).
- False-positive Rate: For PIR detections across different settings (pet/no-pet scenarios).
- Uptime and Power: System uptime across C continuous days and average current draw.

➤ *Testbed*

We test in a simulated home environment with controlled scenarios:

- Health Event: Elevated heart rate simulation (exercise) to validate critical alerting.
- Intrusion Event: Simulated door opening at night to test

security alerting.

- Network Failure: Disable Wi-Fi to verify GSM fallback.
- Panic Button: Manual press to test immediate cascade of alerts.

**IX. RESULTS AND DISCUSSION**

The following are suggested contents for your experimental results. Add measured numbers to replace placeholders.

➤ *Latency Measurements*

- Local buzzer latency: ~0.4–1.2 s (sensor-to-actuator).
- MQTT publish to broker (on local LAN): ~0.2–0.8 s.
- GSM SMS delivery (typical): ~5–20 s (carrier dependent).

➤ *Accuracy*

When tested against a clinical-grade pulse oximeter:

- Mean Absolute Error (MAE) for heart rate: X bpm (replace with measured).
- Temperature MAE vs. reference thermometer: Y°C.

➤ *Reliability and Case Studies*

Case studies demonstrate that the system:

- Successfully reported events to ThingSpeak within 2 seconds on average.
- Used GSM fallback to deliver SMS during Wi-Fi outage scenarios in all test runs (100% of tests; replace after your runs).

➤ *Discussion*• *Discuss Trade-Offs:*

Cheaper sensors may bias measurements requiring calibration; GSM increases power and cost but offers essential redundancy; cloud dashboards ease caregiver monitoring but introduce privacy considerations (next section).

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**X. PRIVACY, SECURITY AND ETHICAL CONSIDERATIONS**➤ *Elder Care Systems Handle Sensitive Health Data; Therefore:*

- Use secure MQTT with TLS for encrypted transport when possible.
- Store minimal telemetry on cloud; use access controls and API keys for ThingSpeak or any dashboard.
- Local storage (on-device) should be minimal; prefer ephemeral buffers and offload storage to authorized services.
- Get informed consent from the monitored person and provide a clear privacy policy.

**XI. ADVANTAGES AND DISADVANTAGES**➤ *Advantages*

- Integrated architecture reduces fragmentation between health and safety monitoring.
- Dual notification (internet + GSM) increases resilience.
- Low-cost hardware allows for scalable deployments.
- Modular and extendable — adding fall detection or wearables is straightforward.

➤ *Disadvantages*

- Low-cost sensors require careful calibration and periodic validation.
- GSM fallback increases operating costs (SIM/data/SMS).
- Privacy risks if cloud or device is misconfigured; security hardening is required.

**XII. FUTURE WORK**➤ *Possible Directions to Expand the System:*

- **Fall Detection:** Integrate accelerometers (on furniture or wearables) with ML models to detect falls.
- **Anomaly Detection:** Use time-series ML (LSTM or Gaussian Processes) to learn personalized baselines and detect anomalies.
- **Mobile App with ACK Flow:** Caregiver app that shows events and requires acknowledgment to prevent duplicate alerts.
- **Energy Harvesting:** Explore solar or energy-harvesting sensors to reduce maintenance.
- **Edge Security:** Implement secure boot and signed firmware for tamper resistance.

**APPENDIX****APPENDIX A: ESP8266 SKETCH OUTLINE (ARDUINO)**

```

/* Outline: ESP8266 Elder Care Sketch
  - Reads Pulse sensor, DHT11, PIR, Door sensor
  - Publishes telemetry to MQTT (ThingSpeak)
  - Uses SIM900A for SMS fallback (AT commands)
  - Triggers buzzer/LED on alerts
*/

// Include libraries
#include <ESP8266WiFi.h>
#include <PubSubClient.h>
#include "DHT.h"

// Define pins
#define PULSE_PIN A0
#define DHT_PIN D2
#define PIR_PIN D5
#define DOOR_PIN D6
#define BUZZER_PIN D7
#define PANIC_PIN D8

// DHT settings
DHT dht(DHT_PIN, DHT11);

// WiFi and MQTT settings
const char* ssid = "YOUR_SSID";
const char* password = "YOUR_PASS";
const char* mqtt_server = "broker.hivemq.com"; // or your broker
PubSubClient client(wifiClient);

// SIM900A serial (SoftwareSerial or use Serial1)
void sendSMS(const char* number, const char* message) {
  // AT command flow to send SMS via SIM900A
}

// Setup function
void setup() {
  Serial.begin(115200);
  dht.begin();
  pinMode(PIR_PIN, INPUT);
  pinMode(DOOR_PIN, INPUT_PULLUP);
  pinMode(BUZZER_PIN, OUTPUT);
  pinMode(PANIC_PIN, INPUT_PULLUP);
  // Connect to WiFi, setup MQTT callbacks
}

// Main loop
void loop() {
  // Read sensors: pulse, dht, pir, door
  // Filter pulse (moving average)
  // Check thresholds and event logic
  // If alert -> trigger local buzzer and send mqtt aler
  // If no WiFi -> try GSM fallback
  // Publish regular telemetry
  delay(1000);
}

```