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ORIGINAL CONTRIBUTION

Design and Experimental Demonstration of an IoT-Enabled Multi-Parameter Health and Environmental Monitoring System Using ESP32 and Blynk

¹Sabyasachi Dey, ²Gouri Shankar Paul, ³Abhishek Samanta

^{1,2,3}*Department of Electrical Engineering, Global Institute of Science & Technology, Haldia, Purba Medinipur, West Bengal, India*

ABSTRACT

Remote health monitoring requires compact sensing, local processing, and reliable access to physiological data. This paper presents a low-cost IoT health monitoring prototype using an ESP32, MAX30102 pulse-oximetry sensor, DS18B20 temperature sensor, DHT11 temperature-humidity sensor, 0.96-inch OLED, and Blynk platform. The system measures heart rate, SpO₂, body temperature, ambient temperature, and humidity. The ESP32 collects sensor data, displays readings on the OLED, and transmits them via Wi-Fi to a Blynk dashboard. The firmware uses a 100-sample red/infrared acquisition window and a 2-second reporting interval. The prototype demonstrates simultaneous local and remote monitoring of all five parameters. It is intended for educational and preliminary monitoring applications rather than clinical use. Future validation will assess accuracy, repeatability, communication latency, and data availability.

KEYWORDS: Internet of Things; remote health monitoring; ESP32; MAX30102; SpO₂; body temperature; DHT11; Blynk IoT; embedded sensing; remote visualization.

1. INTRODUCTION

The Internet of Things (IoT) is increasingly being used to connect sensors, embedded controllers, communication networks, and software services for continuous monitoring [1], [2]. In healthcare, IoT-based architectures support remote patient monitoring by enabling physiological measurements to be acquired digitally and transmitted for remote visualization [3], [6]. Such systems can be useful in home-care environments, small clinics, and other situations where continuous observation by clinical staff may be impractical. Recent developments in wearable and embedded IoT systems have demonstrated the feasibility of

combining low-cost sensors, microcontrollers, wireless communication, and cloud platforms for health-monitoring applications [3]–[6].

The prototype presented in this work was originally developed as a diploma-level project and integrates an ESP32 microcontroller with a MAX30102 pulse-oximetry sensor, a DS18B20 digital temperature sensor, a DHT11 temperature-humidity sensor, and an OLED display [4], [7], [8]. The system acquires five parameters: heart rate, peripheral oxygen saturation (SpO₂), body temperature, room temperature, and relative humidity. The measurements are displayed locally on the

OLED and transmitted through Wi-Fi to a Blynk IoT dashboard [5], [8], [9]. The use of the MAX30102 and ESP32 is consistent with previous low-cost IoT health-monitoring implementations, which have demonstrated their practicality for remote heart-rate and SpO₂ monitoring [4]–[7].

However, existing student-level implementations frequently emphasize functional demonstration, such as displaying sensor readings or transmitting data to a cloud interface, rather than systematically evaluating measurement performance. For a research-oriented engineering study, functional integration should be distinguished from measurement validity. A connected health-monitoring prototype should specify the sensing and acquisition method, sampling window, communication interval, interface mapping, experimental conditions, reference instruments, repeatability, measurement error, latency, and data availability. Without such evaluation, successful sensor integration alone is insufficient to establish the accuracy or reliability of the system.

The research gap addressed in this work is therefore an integration-and-validation gap at the low-cost prototype level. The proposed system combines physiological and environmental sensing, local visualization, and cloud-based monitoring within a single ESP32 node while establishing a structured framework for evaluating measurement and communication performance. The work deliberately limits its claims to prototype-level operation and does not present the system as a clinically validated or certified medical device. This distinction is important because the supplied project documentation does not include a controlled multi-subject accuracy study against clinically validated reference instruments.

The primary objectives of the developed prototype are to: (1) acquire heart rate and SpO₂ using an optical pulse-oximetry sensor; (2) measure body temperature using a digital temperature sensor; (3) measure ambient

temperature and relative humidity; (4) process the sensor outputs using an ESP32; (5) display the measured parameters locally using an OLED; (6) transmit the readings through Wi-Fi to a Blynk IoT dashboard; and (7) provide a modular platform that can be extended with additional sensors and analytical functions.

The principal contributions of this paper are: (1) integration of physiological and ambient sensing within a single ESP32-based monitoring node; (2) dual visualization through a local OLED display and a remote Blynk IoT dashboard; (3) integration of I²C, 1-Wire, and digital sensing interfaces within a unified acquisition system; (4) documentation of the implemented system parameters, including sensor interfacing, pin allocation, virtual-channel mapping, and nominal reporting period; and (5) definition of a publication-oriented validation methodology covering measurement accuracy, repeatability, communication latency, and data availability. These contributions provide a reproducible engineering framework for evaluating and subsequently improving low-cost IoT-based health-monitoring prototypes.

2. PROPOSED SYSTEM ARCHITECTURE

The proposed architecture consists of four functional layers: sensing, edge processing, communication, and visualization. The sensing layer contains the MAX30102, DS18B20, and DHT11. The ESP32 forms the edge-processing layer and is responsible for initialization, sensor acquisition, pulse-oximetry calculation, formatting, and display management. Wi-Fi provides the communication link between the ESP32 and the Blynk IoT service. The visualization layer consists of the 0.96-inch OLED and the Blynk mobile/web interface.

The MAX30102 communicates with the ESP32 through I²C and provides red and infrared optical measurements used by the pulse-oximetry algorithm. The DS18B20 communicates through the 1-Wire protocol and is used for body-temperature measurement. The DHT11 provides

digital ambient temperature and relative-humidity readings. The OLED is also connected through I²C. The supplied circuit documentation shows the I²C lines connected to ESP32 GPIO21 (SDA) and GPIO22 (SCL). The DHT11 data line is assigned to GPIO18, while the DS18B20 data line is assigned to GPIO5 with a 4.7-k Ω pull-up resistor.

The firmware maps the measured variables to five Blynk virtual channels: V0 for heart rate, V1 for SpO₂, V2 for body temperature, V3 for room temperature, and V4 for humidity. The project code also contains a lightweight HTTP endpoint for displaying the same values in a local web page; this function is treated as an auxiliary feature rather than the primary remote interface in this paper.

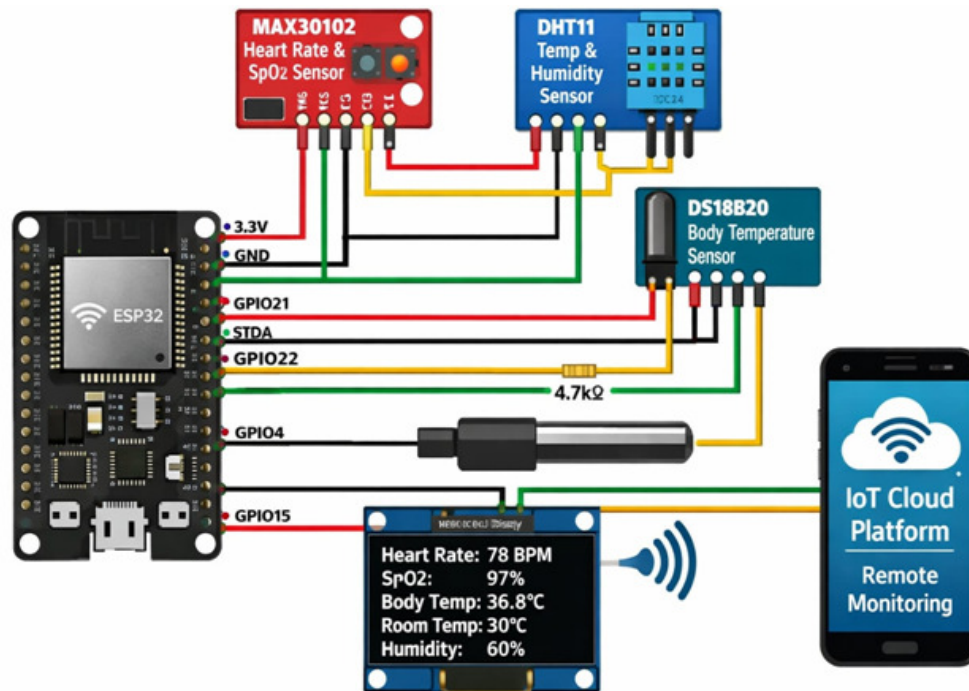


Figure 1. Integrated hardware and communication architecture of the ESP32-based monitoring prototype. The diagram also shows the representative local OLED output documented in the project report.

3. HARDWARE IMPLEMENTATION

A. ESP32 Development Board. The ESP32 is the central controller and communication node. Its Wi-Fi capability enables direct Internet connectivity without an external Wi-Fi module. The device also provides I²C and general-purpose digital interfaces required by the selected sensors and display.

B. MAX30102 Pulse-Oximetry Sensor. The MAX30102 is an optical sensor designed for heart rate and pulse oximetry applications. It uses red and infrared light-emitting elements and a photodetector to obtain photoplethysmography

information. In the prototype, the sensor is read through the I²C bus. The firmware collects 100 red and 100 infrared samples and passes the arrays to the pulse-oximetry routine to estimate heart rate and SpO₂.

C. DS18B20 Body-Temperature Sensor. The DS18B20 is a digital temperature sensor using the 1-Wire protocol. It is connected to GPIO5 and accessed through the Dallas Temperature library. The prototype reads the first sensor on the 1-Wire bus and reports the result in degrees Celsius.

D. DHT11 Ambient Sensor. The DHT11 is used to measure room temperature and relative humidity. Its data line is connected to GPIO18. The values are read using the DHT library and transmitted to the local and remote interfaces.

E. OLED Display. A 0.96-inch, 128 × 64 OLED module is used for local visualization. The display presents room temperature, humidity, body temperature, heart rate, and SpO_2 in a compact format.

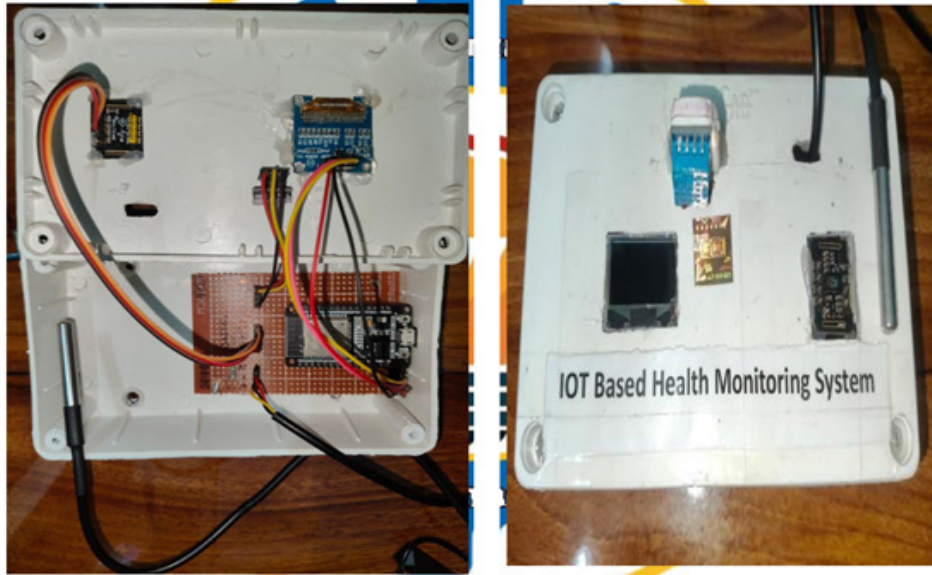


Figure 2. Experimental hardware prototype: (a) internal sensor/controller assembly and (b) assembled enclosure with the sensing elements and display

F. Blynk IoT Platform. Blynk provides the software layer for remote visualization. The platform supports connected-device monitoring, mobile/web dashboards, and data access through

its cloud infrastructure. In this implementation, the ESP32 sends five variables to predefined virtual channels, allowing the user to view the measurements remotely.

Table 1. Hardware and interface summary

Component	Measured/Served Parameter	Interface	ESP32 Assignment
ESP32 DevKit V1	Controller and Wi-Fi	—	Central controller
MAX30102	Heart rate, SpO_2	I ² C	SDA GPIO21, SCL GPIO22
DS18B20	Body temperature	1-Wire	GPIO5
DHT11	Room temperature, humidity	Digital	GPIO18
0.96-in OLED	Local display	I ² C	SDA GPIO21, SCL GPIO22
Blynk IoT	Remote visualization	Wi-Fi	V0–V4

4. SOFTWARE AND DATA-ACQUISITION METHOD

The firmware was developed for the ESP32 using an Arduino-compatible development environment. The principal libraries identified in

the supplied code are WiFi.h, BlynkSimpleEsp32.h, Wire.h, MAX30105.h, spo2_algorithm.h, OneWire.h,

DallasTemperature.h, DHT.h, Adafruit_GFX.h, and Adafruit_SSD1306.h.

During initialization, the ESP32 establishes the I²C interface, starts the OLED, connects to Blynk through Wi-Fi, initializes the DHT11 and DS18B20 interfaces, and checks for the presence of the MAX30102. The MAX30102 is configured with a low red-LED drive value and the green LED disabled. A Blynk timer is configured with a nominal period of 2000 ms.

During each acquisition cycle, the DHT11 temperature and humidity are read, the DS18B20 conversion is requested, and 100 red/infrared samples are collected from the MAX30102. The sample arrays are passed to the Maxim pulse-

rate and oxygen-saturation routine, which returns heart rate and SpO₂ estimates together with validity indicators. The current values are then written to the OLED and to Blynk virtual channels V0–V4.

The software architecture is intentionally simple and deterministic. It is appropriate for a prototype because the data path from sensor to dashboard can be traced directly. For a research-grade implementation, the firmware should also record timestamps, sensor-validity flags, Wi-Fi status, packet/update success, and optical signal quality indicators. These additions would make subsequent accuracy and reliability analysis substantially stronger.

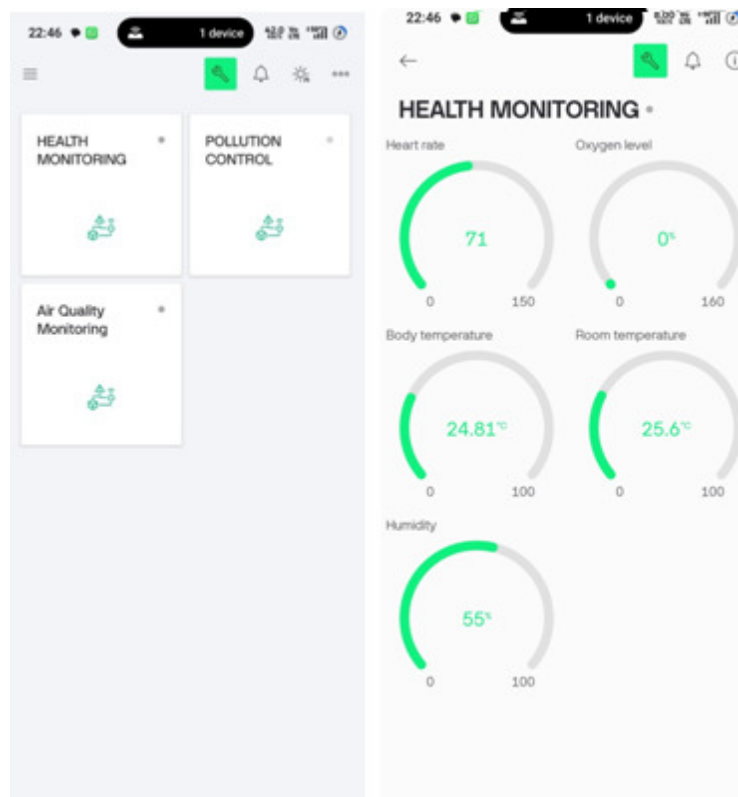


Figure 3. Blynk IoT mobile interface used for remote visualization of the monitored parameters. The supplied prototype report shows two application screens.

Table 2. Blynk data-channel mapping

Virtual Channel	Parameter	Unit
V0	Heart rate	BPM

V1	SpO ₂	%
V2	Body temperature	°C
V3	Room temperature	°C
V4	Relative humidity	%RH

5. EXPERIMENTAL SETUP AND VALIDATION PROTOCOL

The supplied project report demonstrates the working prototype and shows the integrated circuit and Blynk interface. It does not provide a controlled reference-instrument dataset, repeated measurements, participant count, statistical analysis, communication-latency measurements, or sensor-accuracy calculations. Consequently, this paper does not invent such values.

For publication-grade validation, the following protocol is recommended. First, verify sensor repeatability by collecting at least 30 consecutive readings under stable conditions for each parameter. Second, compare heart rate and SpO₂ against a calibrated or commercially available reference pulse oximeter. Third, compare body temperature against a calibrated digital thermometer or medical-grade reference device. Fourth, compare room temperature and humidity against a calibrated thermo-hygrometer. Fifth, measure end-to-end communication latency from acquisition timestamp to Blynk dashboard update. Sixth, calculate data availability as the percentage of scheduled updates successfully received.

For a reference measurement x_{ref} and prototype measurement x_p , the absolute error is $e_{abs} = |x_p - x_{ref}|$. The percentage error is $e_{\%} = \left| \frac{x_p - x_{ref}}{x_{ref}} \right| \times 100$. For N repeated observations, mean absolute error is $MAE = \left(\frac{1}{N} \right) \sum |x_{p,i} - x_{ref,i}|$. Root mean square error is $RMSE = \sqrt{\left(\frac{1}{N} \right) \sum (x_{p,i} - x_{ref,i})^2}$. Data

availability is $A = \left(\frac{N_{received}}{N_{expected}} \right) \times 100\%$.

Bland–Altman analysis may also be considered for heart rate and temperature if sufficient paired reference measurements are collected.

6. Results and Discussion

The prototype successfully integrates five parameters: heart rate, SpO₂, body temperature, room temperature, and humidity. These values are displayed on an OLED and remotely monitored through Blynk using the ESP32. The demonstrated readings confirm system functionality but do not represent clinically validated results.

The main limitation is measurement accuracy. MAX30102 and temperature sensors are affected by factors such as motion, sensor placement, contact, and environmental conditions. Therefore, the system should be considered a low-cost monitoring prototype rather than a diagnostic device. Although SMS, e-mail, and buzzer alerts were proposed in the original report, they are not implemented in the supplied firmware and are excluded from the claimed functionality.

7. Security, Privacy, and Safety

Health data should be protected using secure credentials and restricted dashboard access. Wi-Fi and Blynk credentials must not be included in publications or public repositories and should be regenerated before release. The system is not clinically validated and should not be used for diagnosis or treatment decisions.

8. Limitations and Future Work

The prototype lacks reference-based validation, multi-user testing, uncertainty analysis, long-term stability testing, packet-loss analysis, and formal cyber security assessment. Future work should include comparison with reference instruments, repeated multi-user testing, signal-quality and motion-artifact analysis, time stamped data logging, quantitative error analysis, stronger security, and reliable alert mechanisms.

9. Conclusion

The ESP32-based prototype demonstrates the feasibility of integrating physiological and environmental monitoring with local OLED and remote Blynk visualization. However, clinical accuracy and diagnostic performance cannot be claimed from the available results. Future research should focus on controlled validation, repeated measurements, and quantitative performance evaluation.

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