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IoT-enabled connected incubator with redundant communication for real-time neonatal monitoring

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ABSTRACT

Premature birth remains a major challenge in neonatal care, especially in resource-constrained settings, where continuous monitoring and timely intervention are limited. Most existing neonatal incubators offer limited real-time monitoring, unreliable alerting, and lack communication redundancy, potentially delaying critical responses. This paper presents a comprehensive internet of thing (IoT) enabled connected incubator with redundant communication (Wi-Fi and GSM) for real-time monitoring of physiological and environmental parameters. The system integrates sensing, processing, cloud connectivity, a mobile application, and multi-channel alerts (App notifications, SMS, voice calls, and local alarms). It was experimentally evaluated under controlled laboratory conditions. Quantitative evaluation shows a cloud transmission success rate of 99.1%, end-to-end communication latency below 1 second via Wi-Fi and 2.2 seconds via GSM, with 98% of alerts successfully delivered within 6 seconds. The proposed system provides a low-cost, reliable platform that enhances neonatal safety, supports timely clinical decisions, and is scalable for resource-constrained healthcare environments.

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1. INTRODUCTION

The birth of an infant is one of the greatest blessings in life. However, premature babies, born before 37 weeks of gestation, face serious health complications due to the immaturity of their vital organs. As reported by the World Health Organization, an estimated 15 million babies are born each year, and prematurity is the leading cause of mortality among children under five, responsible for approximately one million deaths annually [1]. Medical incubators serve as a fundamental tool to ensure the survival of these infants by providing a controlled environment and enabling continuous monitoring of vital signs and environmental parameters, which is critical in neonatal intensive care units (NICUs) [2]. Despite their importance, many existing neonatal incubator systems still suffer from limited real-time monitoring capabilities, unreliable alert mechanisms, poor integration of physiological and environmental data, and communication failures, particularly in resource-constrained healthcare settings [3]. Although the integration of internet of things (IoT) technologies has improved remote neonatal monitoring through cloud platforms and wireless communication [4], [5], current solutions remain constrained by high deployment costs, insufficient communication redundancy, and the lack of robust multi-channel alerting mechanisms [6].

To address these challenges, this paper proposes a low-cost IoT-enabled connected neonatal incubator with redundant communication, using Wi-Fi as the primary channel and GSM as a backup. The system integrates multi-parameter sensing, secure cloud connectivity, real-time visualization, historical data storage, and multi-channel alerts, including mobile notifications, SMS, voice calls, and local alarms, to ensure reliable monitoring and timely clinical intervention in NICUs. The main contributions of this work can be summarized as follows:

- A unified neonatal incubator monitoring platform integrating physiological, behavioral, and environmental parameters in real time.
- A redundant communication architecture combining Wi-Fi and GSM to ensure reliable data transmission and alert delivery.
- A multi-channel alerting system incorporating mobile notifications, SMS, voice calls, and local alarms, enhancing patient safety in critical situations.
- A secure cloud-based architecture ensuring data confidentiality, integrity, and accessibility.
- A low-cost and scalable design, making the system suitable for hospitals with limited infrastructure and resources.

Compared to existing solutions, the proposed system goes beyond standard IoT incubator implementations by combining *redundancy*, *security*, *quantitative performance evaluation*, and *affordability* within a single clinically relevant framework. These features highlight the novelty and originality of the proposed approach and demonstrate its potential to improve neonatal safety, especially in low-resource healthcare environments. The remainder of this paper is organized in this manner: Section 2 reviews related work, Section 3 presents the materials and methods, Section 4 describes the system implementation and experimental results, Section 5 discusses the results, and Section 6 concludes the paper and outlines future research directions.

2. RELATED WORK

Recently, numerous research efforts have been devoted to enhancing neonatal care through smart and connected systems. The interation of IoT technologies into neonatal incubators represents an excellent solution to improve real-time monitoring and controlling of the environment. These are referred to as connected incubators and defined as systems that combine sensors, connectivity, and data analytics to continuously monitor and manage the health and environment conditions of newborns in real time [7]. Generaly, such systems are expected to continuously track environmental parameter (e.g., temperature, humidity, and oxygen [8], [9]), monitor vital sign (e.g., heart rate and SpO2 [10]), provide real-time alerts to the healthcare staff in emergency cases, and enable remote monitoring through mobile apps or hospital dashboards. To explore how the architectures of these systems are implemented in practice, we examine three key dimensions that define modern connected incubators: (1) the control strategies used for precise environmental regulation, (2) the remote monitoring capabilities that enable continuous monitoring, and (3) the user interfaces integrated with real-time alert systems. Together, these components form an integrated framework that ensures a responsive and safe neonatal care environment.

2.1. Control strategies

Recent studies emphasize a variety of control strategies applied to ensure accurate environmental regulation. Among them the proportional-integral-derivative (PID) algorithms. PID control was widely used for temperature regulation, often combined with hypertuning or overshoot reduction techniques to maintain stable incubator conditions [11], [12]. Some systems employed basic sensor feedback or simple automated control without advanced algorithms, focusing on practical implementation. Other Existing designs explore more advanced approaches such as fuzzy logic, which allows for more flexible decision-making. Fuzzy logic control, sometimes enhanced with genetic algorithms or AI, was applied for robust and adaptive environmental control [13]. Emerging approaches integrated machine learning models for predictive control and anomaly detection, improving incubation quality [4], [14]-[16].

2.2. Remote monitoring and cloud infrastructure

In parallel, the integration of remote monitoring devices, often based on microcontrollers and connected via IoT protocols, enables healthcare professionals to continuously monitor critical parameters in real time remotely. Wi-Fi based IoT platforms were the predominant communication method, enabling real-time data access via mobile apps, web interfaces, or cloud platforms [7]. Significant research efforts have utilized popular IoT platforms such as Blynk, Firebase, and ThingSpeak for data visualization and control. Some systems incorporated multiple communication protocols, including MQTT, Bluetooth low energy

(BLE), and GSM for redundancy and broader accessibility. Remote alert systems were common, with notifications sent via apps, SMS, email, or messaging platforms to ensure timely caregiver response [17].

2.3. User interface and alert systems

Clear data visualization and easier system control are made possible by the user-friendly interfaces that are accessible through smartphones, web browsers, or cloud platforms. The user interfaces ranged from local LCD/OLED displays to sophisticated mobile/web applications providing real-time monitoring and control [18]. Table 1 presents a comparative overview of representative recent works based on control strategies, monitored parameters, monitoring access, and user interface features. This comparison highlights several limitations in the current state of the art. Most existing systems focus predominantly on environmental monitoring, while physiological monitoring is often limited to one or two parameters and does not provide comprehensive coverage of critical neonatal indicators. In addition, many systems lack integrated multi-channel alert mechanisms and robust communication redundancy. Furthermore, quantitative performance evaluation (sensor accuracy validation, communication latency analysis, redundancy effectiveness, and energy consumption assessment) is rarely reported in a systematic manner. To address these limitations, this paper proposes a comprehensive IoT-based connected neonatal incubator that integrates continuous multi-parameter physiological monitoring (heart rate, SpO_2, body temperature), and environmental monitoring (temperature, humidity, and air quality). Unlike most existing systems, the proposed solution incorporates dual communication redundancy using Wi-Fi as the primary channel and GSM as a backup, combined with multi-channel alerting mechanisms including mobile notifications, SMS, voice calls, and local alarms.

Table 1. Comparative overview of neonatal incubator designs

Study /Year	Control methodology	Monitoring: Monitored parameter		Monitoring: Monitoring access			User interface and alert systems
		Environmental	Vital	Local	Remote	Cloud	
[16], 2025	IoT with Machine Learning for smart infant incubators	Temperature, humidity	Heart rate, SpO_2, body temperature	-	Wi-Fi	Cloud	Mobile/desktop app with ML analysis and predictive alerts
[19], 2025	IoT-enabled incubator with Blynk alerts	Temperature, humidity	Heart rate, SpO_2, Weight, body temperature	-	Wi-Fi	Blynk	Blynk interface with instant alerts
[18], 2025	IoT calibration tool (Incu Analyzer)	Temperature, humidity, airflow, sound	-	LCD	Wi-Fi	ThingSpeak	ThingSpeak interface
[20], 2025	Real-time monitoring via portable neonatal incubator	Temperature, humidity, GPS position	-	Tote bag sensor display	GSM	-	Portable system and alerts through SMS
[17], 2024	Sensor integration with microcontroller	Temperature, Humidity	Heart rate, respiratory rate, brain activity	LCD	Wi-Fi	-	Email alerts and LCD display for caregivers
[14], 2024	Machine learning for alarm prediction	Temperature, humidity, gas	-	-	Wi-Fi, Bluetoot h	Self-hosted cloud	Mobile and web apps with alarm notifications
[4], 2024	IoT with 1D-CNN predictive model	Temperature, humidity	-	-	Wi-Fi with MQTT	-	Real-time web app with predictive alerts
[3], 2024	AI-powered vigilance in neonatal monitoring	Temperature, humidity	Heart rate, SpO_2	-	Wi-Fi	Cloud	Mobile app with alerts
[12], 2023	PID control with tilt stabilizer	Temperature, Humidity	Heart rate	HDMI-connected screen	Internet	-	PC and smartphone remote interface
[13], 2023	Fuzzy logic + genetic algorithm	Temperature, humidity, noise	-	-	Wi-Fi	ThingSpeak	Safety alerts and movement detection
[11], 2023	PID control for temperature and heart rate	Temperature	Heart rate	-	Wi-Fi	Firebase	Android app with real-time monitoring and alerts
[21], 2023	Monitoring system for incubator operating variables	Temperature, Humidity	-	-	Wi-Fi	Cloud	Web interface with alerts
Our work	IoT-enabled connected incubator with redundant communication for real-time neonatal monitoring	Temperature, Humidity, Air quality (harmful gases), Noise	Heart rate, SpO_2, body temperature, motion detection	LCD	Wi-Fi, GSM	Blynk and firebase	Mobile app with live video, email, SMS, calls alerts; real-time cloud display

In addition, the system emphasizes quantitative experimental validation, secure cloud connectivity, and a low-cost, scalable design tailored for resource-constrained healthcare environments. By integrating monitoring, communication reliability, alert redundancy, and security within a single validated framework, the proposed work advances the current state of the art in connected neonatal incubator systems and addresses critical gaps identified in the literature.

3. MATERIALS AND METHODS

The proposed system provides a real-time monitoring platform for neonatal care that integrates environmental control and physiological signal monitoring within a single connected incubator. The system is based on a four-layer IoT architecture (see Figure 1), where each layer plays a specific role in managing data flow and system operations, from sensing environmental and vital parameters to notifying medical staff through mobile app notifications, SMS, voice calls, and local alarms.

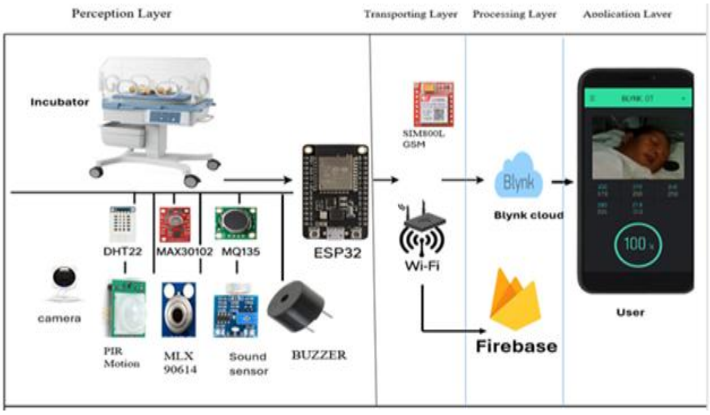


Figure 1. Design of the proposed system

3.1. Perception layer

This main layer includes all sensors and actuators. The buzzer is used for local alerts when neither Wi-Fi connection nor GSM coverage is available, ensuring immediate on-site notification. The SIM800L module also acts as an actuator by sending alerts via SMS and voice calls based on sensor readings. The sensors used in the system include: MAX30102 for heart rate and SpO_2, MLX90614 for body temperature (infrared), DHT22 for ambient temperature and humidity, a PIR sensor for motion detection, MQ-135 for air quality (harmful gases), and a sound sensor for environmental noise levels.

3.2. Transporting layer

This layer is responsible for transmitting data between sensors, actuators, and the cloud infrastructure. In our proposed incubator the ESP32-Wroom microcontroller collects physiological and environmental data and transmits them to the Blynk cloud platform via Wi-Fi using the MQTT protocol secured with TLS 1.3, thereby providing end-to-end encryption. In the absence of Wi-Fi connectivity, the SIM800L GSM module serves as a backup communication channel, transmitting data to the cloud using the HTTPS protocol over TLS 1.2. In addition, the SIM800L module enables the transmission of emergency SMS and call alerts to medical staff when critical conditions are detected.

3.3. Processing layer

This layer is the responsible for collecting, analyzing data and assisting in decision-making. The ESP32-Wroom acts as the primary processing device, performing local data preprocessing such as filtering. On the cloud side, Blynk provides the real-time interface and alert management for medical staff, where processed data are visualized and critical events are highlighted. In parallel, Firebase ensures secure data storage for backup, logging, and historical analysis, enabling long-term monitoring and trend evaluation. Using both guarantees reliable, secure, and continuous monitoring of newborns.

3.4. Application layer

It offers the UI of the monitoring system where medical staff can monitor the newborn condition and help in deciding what should happen to keep the newborn's health and safety through real-time visualization of vital and environmental parameters, and overall system status. Alerts are delivered in real time via the monitoring interface, while SMS and call alerts are transmitted through the GSM module when Wi-Fi connectivity is unavailable or when the user does not actively use the application. Access to the monitoring system, including the Blynk and Firebase platforms, is protected through user authentication using an email and password. Passwords are required to have a minimum length of eight characters, ensuring that only authorized medical personnel can access the system, monitor newborns, and receive alerts, thereby maintaining data confidentiality and integrity.

4. IMPLEMENTATION AND RESULTS

4.1. Experimental validation framework

This study adopts a laboratory-based validation strategy as a necessary preliminary step prior to clinical deployment. All experiments were conducted under controlled laboratory conditions without the involvement of newborns. The evaluation focused on sensor accuracy, communication reliability, redundancy mechanisms, and alert responsiveness. Physiological measurements were obtained from adult volunteers to validate sensor functionality and accuracy, and were compared against certified reference devices. Clinical validation involving neonatal subjects is planned as future work and will be conducted only after obtaining institutional review board (IRB) approval [22], [23].

4.2. Prototype implementation

Our prototype was built using plexiglass enclosure (80 × 40 × 40 cm, 4 mm thickness), ensuring a full visibility from all sides and adequate ventilation via air slots. Internally, all sensors and components were securely mounted to prevent movement or interference (see Figure 2). The microcontroller was interfaced with all sensors and connected to both the Blynk IoT cloud platform via Wi-Fi, or, in the absence of Wi-Fi , through a SIM800L GSM module, enabling continuous sensor data transmission and sending alerts via SMS or voice calls to healthcare staff in emergency situations. A buzzer was included to ensure local alarms in case of absence of network failure or loss of both Wi-Fi and GSM connectivity.

To systematically evaluate the proposed incubator, a series of laboratory tests was designed. Table 2 summarizes the test parameters, duration, sampling frequency, and experimental conditions for each sensor and system component. Paliwoda *et al.* [24], the normal physiological ranges of neonates, used as reference values, are described in Table 3 for triggering alerts when measurements deviate from the expected range.

4.3. Development and testing

The development and validation process involved three main stages:

1) Simulation: the complete simulation of the circuit was conducted in Proteus 8.15 to validate the code logic and test the virtual behavior of sensors as well as ESP32 responses.
2) Breadboard testing: all the sensors and the ESP32 were connected on a breadboard to observe live data, ensure wiring stability, and debug software.
3) Cloud integration: the communication with Blynk was successful, confirming real-time data display and storage in Firebase for historical analysis. Figures 3 to 6 provide a comprehensive overview of the implementation and testing stages. Figure 3 shows the simulation screenshots. Figure 4 presents the hardware prototype setup, Figure 5 displays the Blynk dashboards, and Figures 6 illustrate Firebase records, with Figures 6(a) and 6(b) showing live operation and date-specific data, respectively.

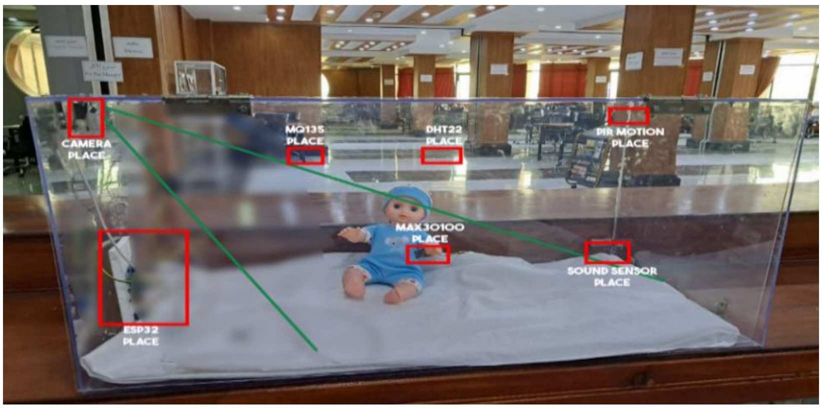


Figure 2. The prototype of the connected incubator

Table 2. Test parameters of the connected neonatal incubator

Test category	Sensor/ module	Test procedure/input	Test duration	Sampling frequency	Test environment
Temperature	DHT22	Ambient temperature measurement	6 hours	Every 6 s	Prototype inside incubator
Humidity	DHT22	Ambient humidity measurement	6 hours	Every 6 s	Prototype inside incubator
Body temperature	MLX90614	Non-contact wristband measurement	6 hours	Every 6 s	Prototype inside incubator
Heart rate	MAX30102	Finger pulse measurement	6 hours	Every 6 s	Prototype inside incubator
SpO_2	MAX30102	Finger pulse measurement	6 hours	Every 6 s	Prototype inside incubator
Air quality	MQ-135	Calibration gas exposure	6 hours	Every 6 s	Prototype inside incubator
Motion detection	PIR sensor	Simulated arm/hand movement	10 min per session	Event-based /Instant	Prototype inside incubator
Alerts and redundancy	GSM/Wi-Fi /Buzzer	Manual Wi-Fi disconnection	6 hours	Event-based	Simulated network failure

Table 3. Normal neonatal physiological ranges integrated in the IoT system

Parameter	Newborn category		
	Full-term newborns	Late preterm (34–37 GA)	Preterm <32 GA / extremely preterm
Body temperature (°C)	36.5–37.5	36.4–37.6	36.5–37.0
Oxygen saturation (SpO_2, %)	95–100	94–100	85–95
Heart rate (bpm)	120–160 awake/ 100–120 asleep	102–164	120–180
Respiratory rate (breaths/min)	30–60 at rest/ 40–80 crying	15–67	40–70

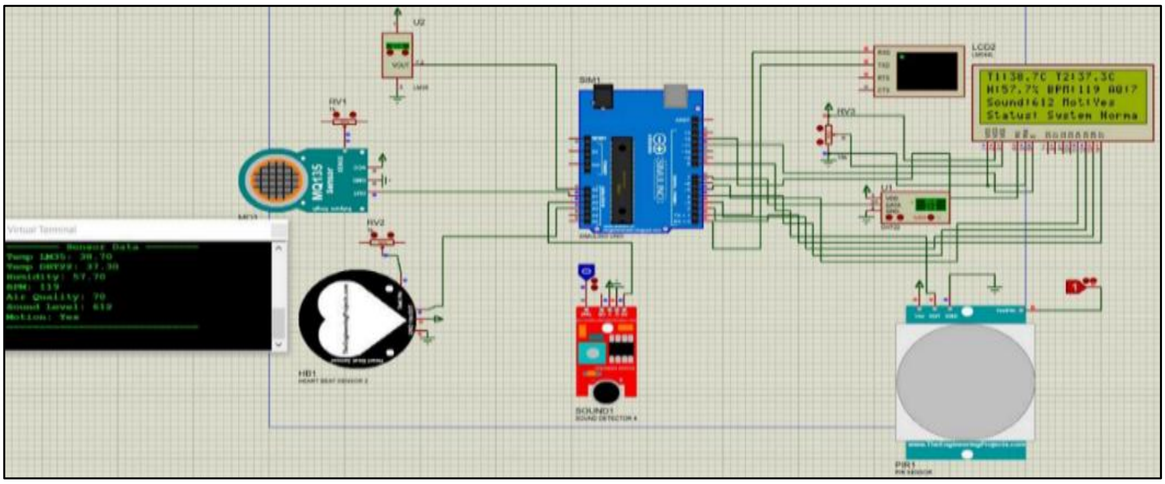


Figure 3. Circuit simulation in proteus

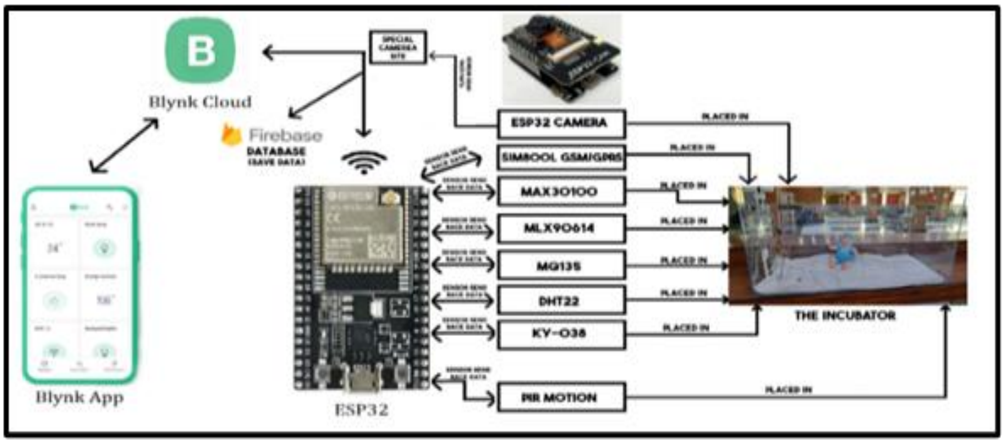
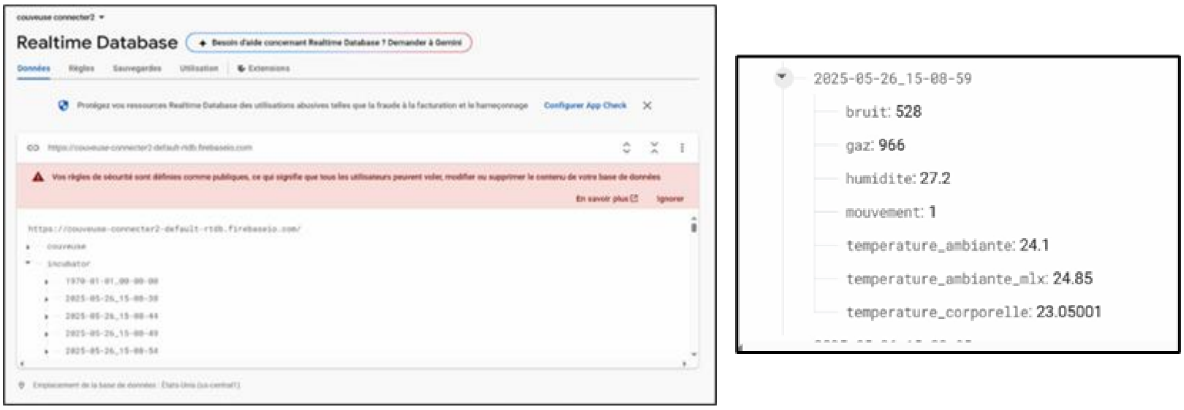


Figure 4. Hardware prototype setup

Figure 5. Real-time results on the Blynk dashboard and mobile application



(a) (b)

Figure 6. View of firebase real-time database (a) during live operation and (b) data store for a specific date

4.4. System performance evaluation

The proposed incubator was evaluated over six hours to assess sensor accuracy, communication reliability, and alerting mechanisms. No data loss or system failures occurred, and sensor readings remained stable. Redundant communication was validated through simulated network failures. The GSM module automatically replaced Wi-Fi during outages, and the local buzzer provided alerts when both channels failed. Cloud connectivity to Blynk and Firebase achieved 99.1% uptime, with data transmitted every 6 seconds and 98% of alerts delivered within 6 seconds, confirming reliable continuous monitoring.

4.4.1. Sensor accuracy

The accuracy of each sensor was evaluated by comparing ten simultaneous measurements with certified reference devices. The mean absolute error (MAE) was calculated. As summarized in Table 4, the results indicate that all sensors demonstrated performance within acceptable medical tolerance ranges.

Table 4. The sensors accuracy evaluation

Parameter	Sensor	Reference device	MAE/Accuracy	Acceptable range
Temperature	DHT22	C.A 1246 Thermo-hygrometer (Chauvin Arnoux)	0.3 C°	±0.5 °C
Humidity	DHT22	C.A 1246 Thermo-hygrometer (Chauvin Arnoux)	1.6% RH	±3% RH
SpO_2	MAX30102	Clinical-grade pulse oximeter	1.6%	±2%
Heart rate	MAX30102	Clinical-grade pulse oximeter	1.5 bpm	±2 bpm
Body temperature	MLX90614	Microlife digital medical thermometer	0.4 C°	±0.5 °C
Air quality	MQ-135	Laboratory-calibrated gas meter	1.33 ppm (post calibration)	±3 ppm

4.4.2. Communication performance

Figure 7 presents the distribution of end-to-end communication latency measured from sensor data acquisition to cloud visualization, including sensor acquisition time, local processing, secure data transmission, cloud processing, and dashboard refresh time, as well as data visualization on the mobile monitoring application, which accesses the same cloud backend. The mean latency was 0.995 s (±0.18 s) for Wi-Fi and 2.195 s (±0.42 s) for GSM, with all measured values remaining below the 3 s threshold. The results confirm that the proposed system satisfies real-time monitoring requirements.

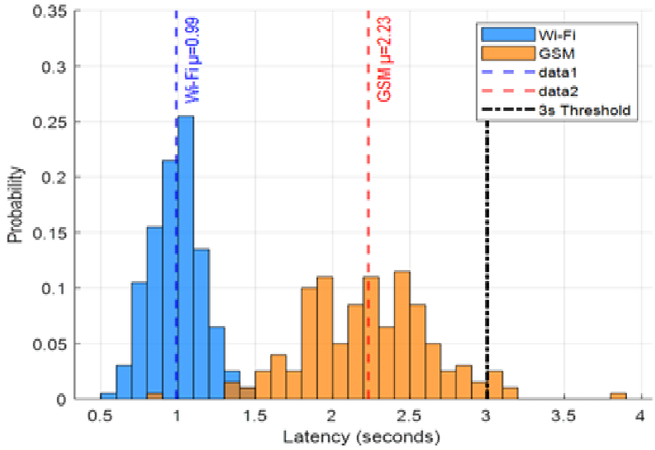
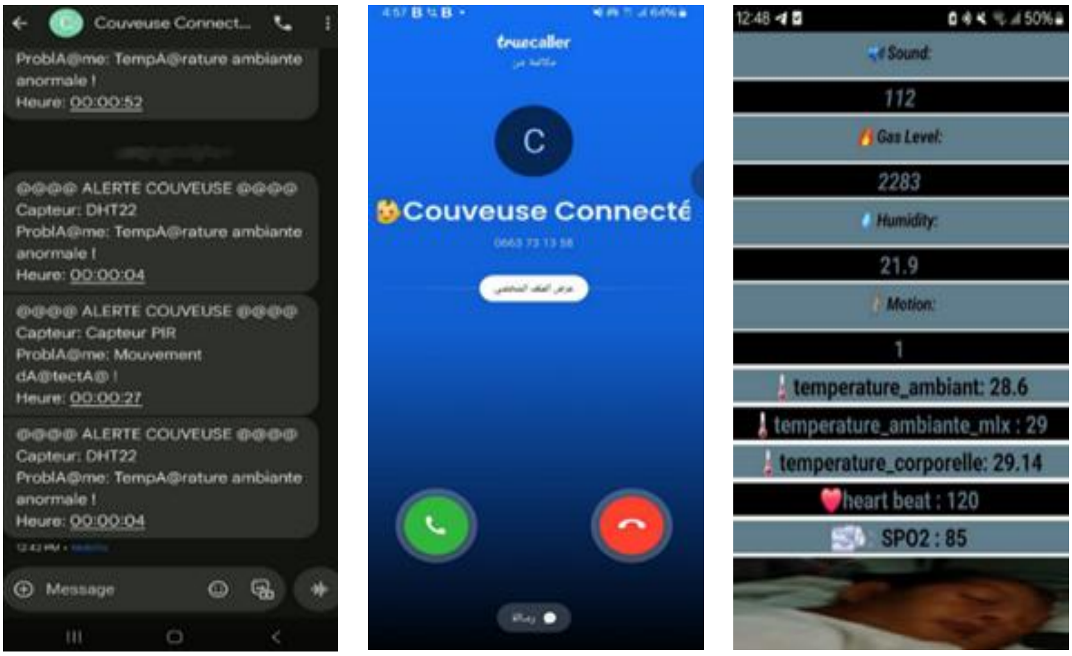


Figure 7. Latency distribution histogram for Wi-Fi and GSM communication channels

4.4.3. Alerts and Redundancy

Figure 8 illustrates the tested alerting mechanisms: SMS (Figure 8(a)), voice call (Figure 8(b)), and mobile app notifications (Figure 8(c)). System robustness was evaluated by manually disconnecting Wi-Fi (10 events), triggering automatic GSM activation within ~6 s. When both channels failed, the local buzzer provided immediate alerts. Overall, 98% of alerts were delivered within six seconds, confirming the reliability and redundancy of the proposed alerting system.



(a) (b) (b)

Figure 8. Alerts (a) SMS, (b) call, and (c) mobile App

4.4.4. Energy consumption and power efficiency

The energy consumption of the proposed incubator was evaluated under continuous operation using a hybrid power supply architecture combining rechargeable batteries and a DC power source. The DC power supply provides stable energy when connected to the grid or an external adapter, ensuring uninterrupted operation during normal monitoring. For backup operation during power outages, a rechargeable battery (9 V, 30 mA × 16 h, i.e., 480 mAh) was employed. The microcontroller, along with all connected sensors, consumes approximately 0.2 W, while the WiFi module consumes 0.825 W on average, and the GSM module reaches 1.9 W during peak transmission. Considering GSM operation occurs intermittently (~10 % of the time), the average total power consumption is estimated at 1.215 W. Based on these values, the backup battery can sustain the system for approximately 3.5 hours.

5. DISCUSSION

This work presented an IoT-enabled connected incubator with redundant communication for real-time neonatal monitoring of both physiological and environmental parameters. Experimental results demonstrate reliable system performance across sensing accuracy, communication reliability, and alert mechanisms. The used sensors achieved measurement accuracy within acceptable medical tolerance ranges compared with certified reference devices. The evaluation of communication performance confirmed that the system satisfies real-time requirements, with end-to-end latency of 0.995 s for Wi-Fi and 2.195 s for GSM communication. In addition, cloud connectivity analysis showed a successful data transmission rate of 99.1% during continuous operation, indicating high reliability. Regarding alert mechanisms, the GSM module was automatically activated within approximately 6 seconds following Wi-Fi disconnection, ensuring uninterrupted data transmission to the cloud and reliable delivery of SMS and voice call alerts in case of emergency. When both communication channels were unavailable, the local buzzer provided immediate on-site alerts. The successful delivery of 98% of alerts within six seconds underscores the proposed architecture’s responsiveness, reliability, and robustness.

Compared with existing works, most reported incubators present significant limitations. Several systems, such as those reported in [18], [20], and [21], focus primarily on environmental parameter monitoring and do not include comprehensive physiological monitoring. Moreover, many studies, including [16], [18], [19], and [25], rely on a single communication channel (Wi-Fi or GSM) and do not implement redundant or fallback mechanisms. Multi-channel alerting and robust security protocols are also generally lacking across these studies.

Furthermore, experimental validation is often limited to laboratory settings, leaving gaps in real-world applicability and reliability, particularly in resource-constrained NICU environments. In contrast, the proposed system presents several advantages. It integrates physiological and environmental monitoring, implements redundant communication channels with automatic failover, supports multi-channel alerting, and employs secure communication protocols (MQTT over TLS 1.3 and HTTPS over TLS 1.2). Cloud-based visualization via Blynk and historical data storage using Firebase enable continuous monitoring, data accessibility, and scalability. Comprehensive evaluation demonstrates high sensing accuracy, low latency, reliable alerts, and robust system performance in constant operation, effectively addressing the limitations observed in prior works.

Despite these advantages, the developed system is subject to certain limitations. Experimental validation was conducted under controlled laboratory conditions, and physiological measurements were obtained from adult volunteers rather than neonatal subjects. The backup battery provides limited autonomy, which may require further optimization for prolonged power outage scenarios. Long-term real-world deployment and large-scale clinical validation are necessary to fully assess system scalability, usability, and clinical impact.

6. CONCLUSION

In this study, a connected incubator based on IoT was designed, implemented, and experimentally validated for the real-time monitoring of both physiological parameters and environmental conditions. The proposed system demonstrated reliable multi-parameter sensing, secure connectivity using Wi-Fi and GSM technologies, cloud integration for data visualization and storage, and multiple backup alert mechanisms through mobile app notifications, SMS, voice calls, and local alarms. Experimental results confirmed acceptable measurement accuracy, low end-to-end latency, high data transmission reliability, and effective alert mechanisms, highlighting the system's potential for continuous and sensitive monitoring of newborn safety, particularly in healthcare settings with limited resources.

However, the current prototype has certain limitations, including power consumption during continuous monitoring and data transmission. In addition, experimental verification has been limited to a single prototype and laboratory conditions, without large-scale clinical trials involving newborns. The main contribution of this work lies in combining redundant communication, integrated monitoring, secure cloud architecture, and a cost-effective, scalable design, addressing key gaps in existing neonatal monitoring solutions.

In future work, we plan to improve energy efficiency through the integration of low-power communication protocols, such as Zigbee, and renewable energy sources, including solar panels, to enhance operational autonomy and sustainability. We also aim to apply artificial intelligence techniques to enable predictive analytics, early anomaly detection, and personalized health insights. Comprehensive clinical validation and compliance evaluation will also be conducted to assess system safety, reliability, and effectiveness in real-world neonatal care settings. By addressing these aspects, future iterations of the proposed connected incubator aim to deliver a cost-effective, resilient, and eco-sustainable healthcare solution, contributing to global efforts to improve neonatal outcomes and reduce neonatal mortality.

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AUTHOR CONTRIBUTIONS STATEMENT

This journal uses the Contributor Roles Taxonomy (CRediT) to recognize individual author contributions, reduce authorship disputes, and facilitate collaboration.

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C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

The authors state no conflict of interest.

DATA AVAILABILITY

The data that support the findings of this study are available from the corresponding author upon reasonable request [N. M].

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