Blynk-Integrated IoT Framework for Real-Time Telemonitoring of Neonatal Weight, SpO_2, and Other Parameters with Instant Alerts

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This Study Was Partially Funded by the Iraqi Ministry of Education and Conducted within the Department of Biomedical Engineering, University of Babylon, Under the Supervision of Dr. Alaa Imran Al-Muttairi.

Publication Date: 2025/09/03

Abstract: The objective of this study is to develop an IoT-enabled neonatal incubator monitoring and alert system that supports remote supervision of infant health. The proposed framework is organized into three core units: a sensor module for biomedical and environmental measurements, a microcontroller for data acquisition and processing, and a cloud-based IoT platform for visualization and notification. The system continuously tracks essential parameters including blood oxygen saturation, heart rate, body temperature, weight, ambient temperature, and humidity within the incubator chamber. Data are transmitted via the NodeMCU microcontroller to the Blynk IoT platform, where they are displayed through a user-friendly graphical interface accessible on both mobile and desktop applications. This allows physicians, nurses, and parents to observe the infant's condition in real time and receive immediate alerts in case of abnormal readings. The design emphasizes cost-effectiveness, scalability, low latency, and adaptability, making it a practical solution for telemedicine and neonatal healthcare. Experimental results validate the system's capability to reliably monitor and transmit data, confirming its potential as a smart healthcare tool.

Keywords: *Smart Neonatal Incubator, Internet of Things (IoT), Nodemcu, Blynk Platform, Remote Infant Monitoring, Wireless Biomedical Sensors, Telemedicine, Real-Time Data Acquisition, Healthcare IoT Applications.*

How to Cite: Ali Sattar Owaid; Hawraa Ali Obead (2025) Blynk-Integrated IoT Framework for Real-Time Telemonitoring of Neonatal Weight, SpO_2, and Other Parameters with Instant Alerts. *International Journal of Innovative Science and Research Technology,* 10 (8), 2027-2034. https://doi.org/10.38124/ijisrt/25aug779

I. INTRODUCTION

Infants delivered before completing 37 weeks of gestation are classified as premature. Such babies require an environment that closely replicates the womb in order to adapt to external conditions. Since their vital organs and enzymatic systems are not fully developed, they need additional care to withstand external factors such as temperature, humidity, oxygen levels, and light. Premature infants also face difficulties in thermoregulation due to their relatively large surface area, limited body mass as a heat reservoir, and insufficient thermal insulation. Furthermore, newborns cannot generate heat by changing posture or adjusting clothing, and these limitations may be worsened by medical conditions such as hypoxia.

To ensure appropriate conditions, premature babies are placed inside an infant incubator, a medical device that provides a stable and protective environment. Structurally, the incubator is a rigid chamber designed to regulate and maintain constant levels of temperature, humidity, and oxygen concentration, thereby supporting the infant's thermoregulation. Functionally, it acts like a specialized air-conditioned enclosure, where environmental parameters can be precisely adjusted based on the baby's health status. Incubators are therefore considered essential for the survival and development of premature or medically fragile newborns [1].

The neonatal incubator provides an enclosed and sterile environment, isolated from dust and bacteria, with the capability to regulate temperature, humidity, and oxygen levels within acceptable ranges. Its primary purpose is to maintain thermal stability for the infant while simultaneously supporting vital physiological functions such as monitoring heart rate, blood pressure, oxygen saturation, and, when necessary, assisting with respiration.

However, conventional incubators are limited by the absence of real-time remote monitoring, which prevents parents and medical staff from continuously supervising the infant's health status. This shortcoming can be critical, as

ISSN No: -2456-2165 https://doi.org/10.38124/ijisrt/25aug779

conditions such as neonatal hyperthermia may result in increased oxygen consumption, dehydration, apnea, or severe weight loss in infants weighing less than 1 kg potentially leading to life-threatening complications. Hence, continuous monitoring of both the infant and the incubator's internal environment is essential to ensure safety and well-being.

To address these limitations, the present study introduces an IoT-enabled neonatal incubator that incorporates advanced remote monitoring capabilities. Through the integration of Internet of Things (IoT) technology, the system continuously measures and transmits key biomedical and environmental parameters such as temperature, humidity, weight, heart rate, and oxygen saturation in real time. This approach enhances neonatal care by enabling timely medical interventions and ensuring that parents and healthcare professionals have immediate access to critical data regarding the infant's condition.

II. MATERIALS & METHODS

Previous works on neonatal incubators have mainly focused on monitoring limited parameters such as temperature or humidity and often aimed to reduce cost. For example, Suruthi and Suma (2015) developed a low-cost incubator with temperature control [2], while Huang and Sun (2015) designed a smart incubator with IoT-based temperature and humidity monitoring [3]. Shakunthala et al. (2018) extended monitoring to heart rate and gas leakage with alert systems [4]. Nwaneri et al. (2019) created a low-cost incubator with real-time environmental monitoring via Wi-Fi [5]. Other studies focused on portable incubators for rural areas or hardware designs using Arduino and Wi-Fi modules [6,7].

Unlike these studies, our project integrates comprehensive real-time monitoring of multiple vital signs including temperature, humidity, weight, heart rate, and blood oxygen using IoT technology. We utilized the Blynk IoT platform, which allows displaying results on multiple devices simultaneously and provides advanced features such as real-time alerts when abnormal parameter levels occur. This enhances infant care by enabling continuous remote access to critical health data and timely intervention [8].

The designed incubator monitoring system is composed of three main components: the data acquisition subsystem, the Internet of Things (IoT) subsystem, and the graphical user interface (GUI). The data acquisition subsystem consists of environmental and biomedical sensors connected to a microcontroller unit, responsible for measuring vital parameters inside the incubator chamber. The IoT subsystem transfers the acquired data to the cloud via an internet connection, while the GUI allows remote viewing of the real-time parameters of the incubator.

The project was divided into several main stages. The first stage involved developing the overall concept of the monitoring system and determining how to implement remote monitoring and alerting using IoT technologies. The second stage focused on hardware design, including electronic circuit design and testing of prototype components. In the third stage, the software for the microcontroller was developed, programmed, and uploaded. Finally, the last stage concentrated on testing the system, connecting it to the internet for displaying measurements, and activating the alert systems in an integrated manner.

➢ *Regarding the Tools Used in this Research, they Included:*

- *NodeMCU – Microcontroller Unit:*
  Selected as the main control unit [9], NodeMCU is a development board based on the ESP8266 chip with a built-in Wi-Fi module. It enables reading, processing, and direct transmission of sensor data to the online monitoring platform. Its ease of programming and full support for IoT applications made it ideal for operating the smart incubator system.

- *Load Cell Weight Sensor with HX711:*
  Used to accurately measure the baby's weight inside the incubator by converting mechanical pressure changes into electrical signals, which are amplified and processed by the HX711 module for precise readings [10].

- *Pulse Oximeter and Heart-Rate Sensor (MAX30100):*
  Measures blood oxygen saturation (SpO_2) and heart rate using red and infrared light technology, allowing continuous monitoring of the infant's vital signs [11].

- *Humidity and Temperature Sensor (RTH03):*
  Measures temperature and humidity inside the incubator to maintain optimal environmental conditions for the baby's growth and to prevent health issues related to overheating or dehydration [12].

- *Human Temperature Sensor (LM35):*
  Directly measures the baby's body temperature with a precise linear output, providing early warnings in the event of abnormal temperature fluctuations [13].

The figure below presents the overall architecture of the implemented incubator monitoring system, which is based on the Internet of Things (IoT) technology.

ISSN No: -2456-2165 https://doi.org/10.38124/ijisrt/25aug779

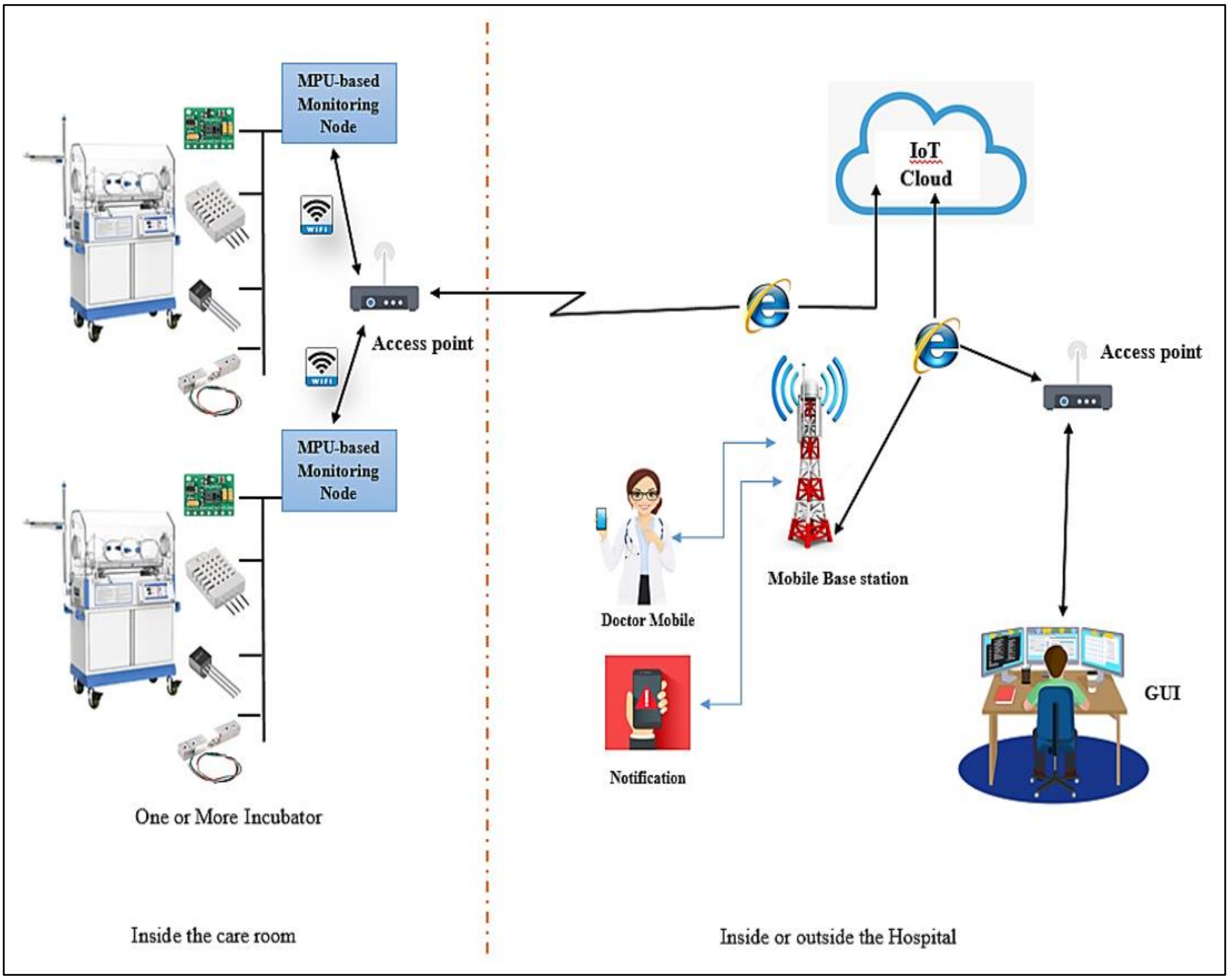

Fig 1 Block Diagram Neonatal Incubator Monitoring System Based on IoT

The incubator monitoring system employs a set of sensors to measure critical parameters in real time, including the baby's body temperature, heart rate, blood oxygen level, weight, as well as the ambient temperature and humidity inside the incubator. These measurements are transmitted to the NodeMCU microcontroller after the programmed code is uploaded. The system begins by initializing the Wi-Fi connection, with the network credentials embedded in the code and uploaded to the NodeMCU. Both an Android device and a computer connect to the NodeMCU via Wi-Fi. The Blynk server is then configured, and the connection is authenticated using a unique token assigned to the device. Control commands, such as operating specific loads, can be sent from the application over the Wi-Fi network to the NodeMCU for execution. Once the measurement data is uploaded to the Blynk IoT platform, it can be monitored in real time through both a computer interface and a mobile phone application.

Prior to developing the final system code, each component was programmed and tested individually to ensure proper functionality. Once all modules operated correctly, the final integrated program was developed and deployed.

The figure below illustrates the operational workflow of the IoT-based neonatal incubator monitoring system. The process begins with the configuration of the NodeMCU hardware and software, followed by the initialization of the Wi-Fi module using pre-defined network credentials. Once the network connection is established, the system connects to the Blynk IoT platform. Subsequently, integrated sensors collect real-time physiological and environmental parameters, including the infant's body temperature, heart rate, blood oxygen saturation, weight, as well as the ambient temperature and humidity inside the incubator. These data are securely transmitted to the Blynk server via a Wi-Fi connection. The server continuously analyzes the incoming measurements from multiple nodes, comparing them against pre-set threshold values. When any parameter exceeds its threshold, the system immediately issues an alert that is displayed on the user interface. Both measurement data and notifications are accessible in real time through desktop and mobile GUIs, ensuring uninterrupted monitoring until the system is manually terminated.

ISSN No: -2456-2165 https://doi.org/10.38124/ijisrt/25aug779

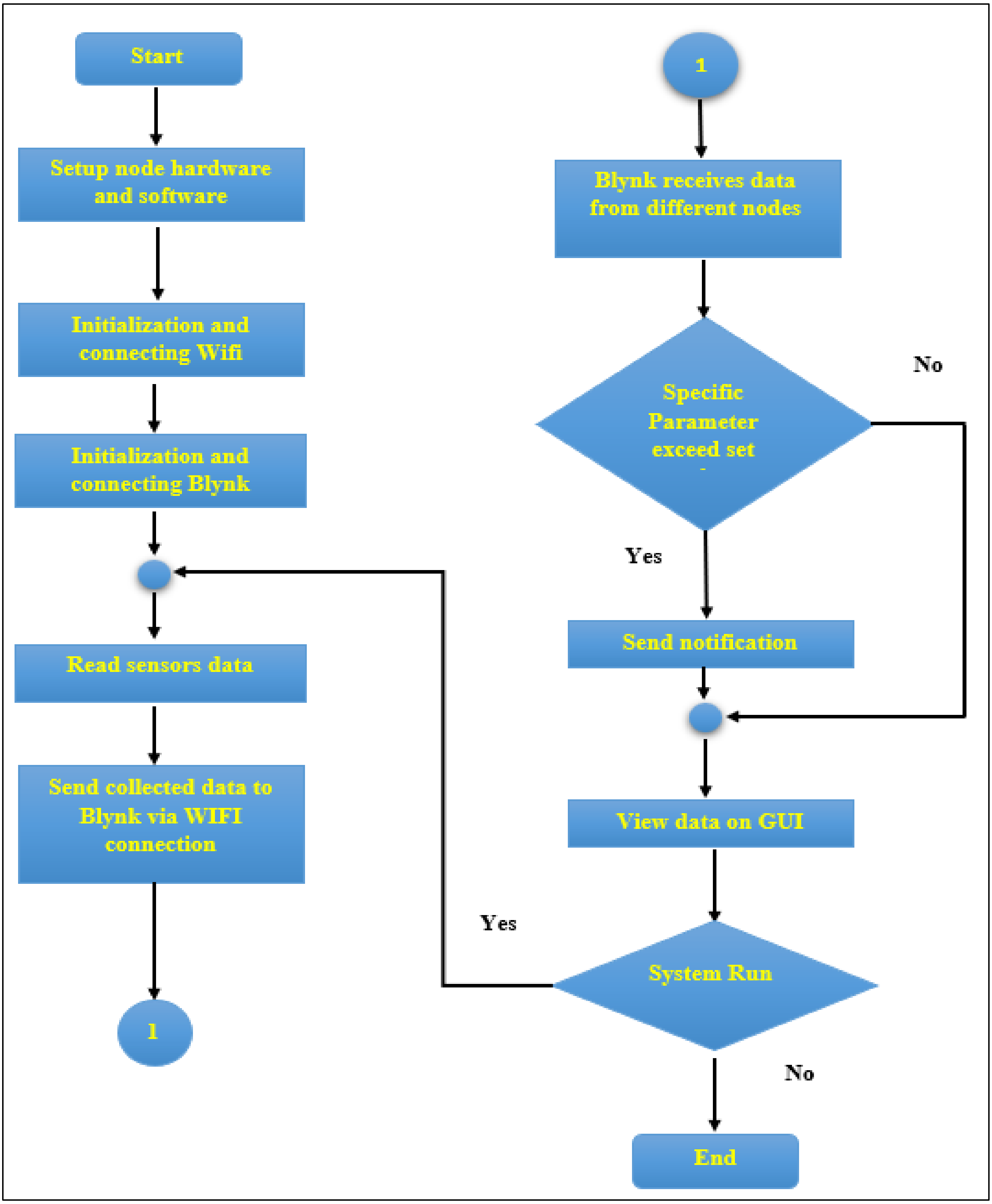

Fig 2 Operational Flowchart of the Designed System

The prototype was initially constructed from wood as a low-cost framework to validate the functionality of the system. Multiple biomedical and environmental sensors, including weight, temperature, humidity, and SpO_2 sensors, were embedded into the structure. The physical implementation of the IoT-based neonatal incubator monitoring system is shown in Fig. 3.

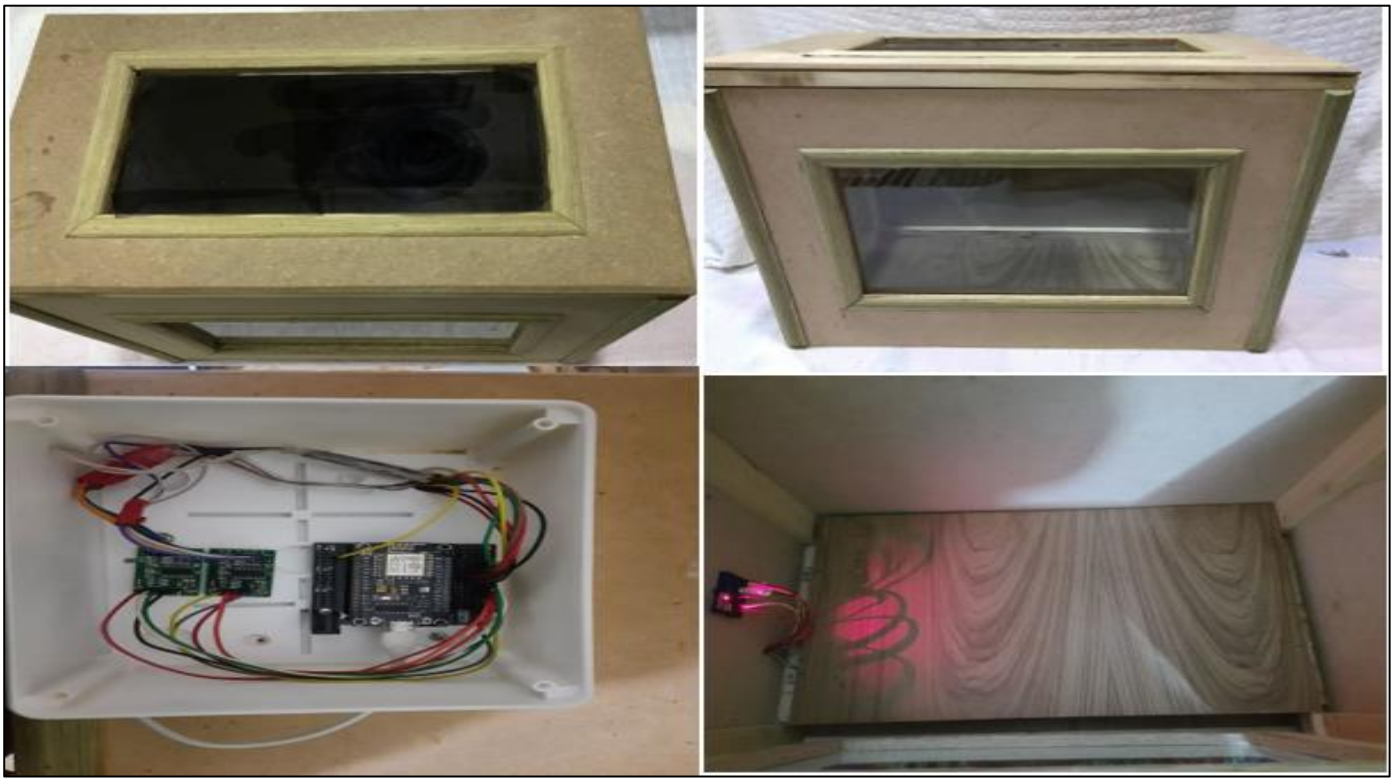

Fig 3 Prototype of the IoT-Based Neonatal Incubator Monitoring System

III. Results

The proposed neonatal incubator monitoring system was implemented and tested to evaluate its ability to measure and remotely monitor key parameters using IoT technology. The experimental results demonstrated reliable performance of the designed system. The figure below presents the graphical user interface (GUI) developed on the Blynk platform, which provides real-time visualization of six critical parameters: infant weight, heart rate, oxygen saturation, body temperature, ambient temperature, and humidity. These values are displayed using analog gauges with numerical indicators, allowing continuous monitoring through both desktop and mobile devices.

Fig 4 Real-Time Infant Incubator Monitoring Through the Blynk IoT GUI on a Computer.

ISSN No: -2456-2165 https://doi.org/10.38124/ijisrt/25aug779

➢ *The Developed System Has Successfully Achieved the following Monitoring and Alerting Functions:*

- *Baby Body Temperature Monitoring*
  - ✓ The system measures the infant's body temperature in real time (°C) using the LM35 temperature sensor.
  - ✓ Readings are continuously updated, enabling immediate detection of abnormal values.

- *Heart Rate and Blood Oxygen Monitoring*
  - ✓ Real-time monitoring of heart rate and blood oxygen saturation (SpO_2) is performed using the MAX30100 sensor.
  - ✓ This ensures continuous observation of the infant's vital signs.

- *Incubator Environment Temperature and Humidity Monitoring*
  - ✓ The RHT03 sensor measures both temperature and humidity inside the enclosure in real time.
  - ✓ This helps maintain an optimal environment for the baby's safety and health.

- *Multi-Platform Monitoring Interface*
  - ✓ Data is displayed in real time on both computer and mobile phone interfaces (as shown in Figure 5), ensuring accessibility for parents and healthcare staff.

- *Automated Notifications via Blynk IoT Platform*
  - ✓ The system sends instant alerts to the phone and computer if any parameter exceeds predefined thresholds.
  - ✓ For example, if the baby's temperature exceeds 37°C or drops below 35°C, an immediate notification is sent to parents or nurses to take prompt action (illustrated in the Figure 5).

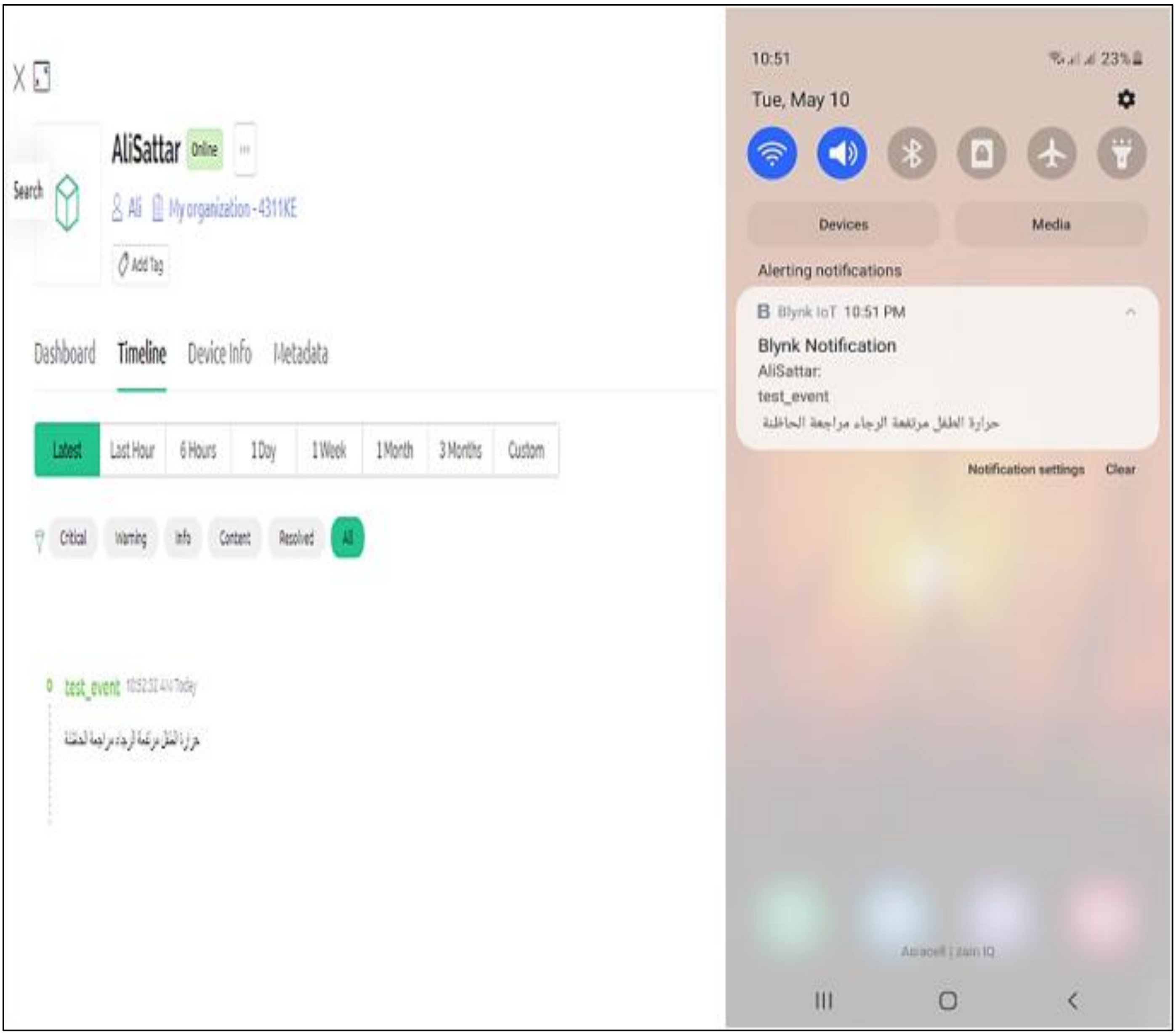

Fig 5 System Notifications Displayed on Both the Phone and Computer

ISSN No: -2456-2165 https://doi.org/10.38124/ijisrt/25aug779

IV. DISCUSSION

The proposed neonatal incubator monitoring system was experimentally validated, and the outcomes were excellent and satisfactory. The key observations and findings from the testing phase are summarized as follows:

- *Efficient Real-Time Data Transmission*
- The system reliably transmitted real-time measurements of infant body temperature, heart rate, blood oxygen saturation, weight, and incubator environmental parameters (temperature and humidity) to the Blynk IoT platform without errors or noticeable latency.

- *Internet Connectivity Issue and Solution*
- Initially, data upload to the Internet faced interruptions due to limited communication capabilities of the original microcontroller. This issue was resolved by replacing it with a new microcontroller, ensuring stable and reliable connectivity.
- *Zero Reading Occurrence in GUI*
- Occasional zero readings were observed in the GUI charts for one or more parameters. This behavior was attributed to compatibility issues between the Arduino platform and the Blynk IoT platform.

- *Weight Sensor Installation Challenge*
- An initial challenge was encountered when installing the weight sensor at the base of the incubator. This issue was resolved by using two weight sensors, resulting in highly accurate and stable measurements.

- *MAX30100 Sensor Performance*
- The MAX30100 sensor demonstrated high accuracy and precision in measuring heart rate and blood oxygen saturation, offering an efficient solution without the complexity typical of such measurements.

- *RHT03 Sensor Performance*
- The RHT03 sensor delivered accurate and precise readings for relative humidity and temperature, making it a reliable option for environmental monitoring inside the incubator without adding measurement complexity.

V. CONCLUSIONS AND FUTURE WORKS

A remote monitoring system for an infant incubator was designed and implemented based on Internet of Things (IoT) technology to support telemedicine applications. The Blynk platform enabled real-time wireless data transmission, aggregation, and analysis. The system integrates two categories of high-quality sensors: biomedical sensors measuring heart rate, blood oxygen saturation, weight, and body temperature, and environmental sensors monitoring temperature and humidity inside the incubator.

A functional prototype, initially fabricated from wood as a low-cost framework, demonstrated the integration and operation of all sensors. Although wood was used for experimental validation, future designs can employ medical-grade materials to ensure clinical suitability.

The design is characterized by low cost, simple implementation, reliability, scalability, and the ability to integrate with one or more incubators. The results demonstrated successful data transmission to the cloud and provided user-friendly graphical interfaces, allowing healthcare workers to access patient data quickly for effective monitoring and decision-making.

For future work, the system can be enhanced by incorporating additional sensors to broaden the scope of remote monitoring. Expanding the design to support multiple incubators with different parameter ranges through separate nodes is also recommended to meet diverse clinical requirements.

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