Comprehensive Iot Model for Healthcare Monitoring Solutionsa Case Study in Nyarugenge Hospital

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Abstract: The Internet of Things (IoT) is revolutionizing various sectors, such as education, healthcare, and smart home technologies. This dissertation focuses on the implementation of an enhanced IoT-based heartbeat and temperature monitoring system at Nyarugenge Hospital. The system incorporates a NodeMCU microcontroller, a 128x64 LCD screen for displaying real-time data on body temperature and heart rate, and sensors like the DS18B20 for temperature measurements and a heartbeat sensor for monitoring cardiac health. By utilizing the Blynk platform, the system enables remote access to sensor data, ensuring continuous monitoring and improved patient care. It also features automatic notifications to doctors through the Mista.io API if a patient's temperature exceeds a preset limit, facilitating timely medical responses. The research explores the effectiveness, reliability, and security of such IoT-based systems while addressing privacy concerns. Additionally, the study highlights the importance of regular health monitoring in preventing conditions associated with poor lifestyle choices, such as obesity, inadequate diet, and lack of physical activity. The proposed system offers a practical and cost-effective solution to enhance healthcare services in resource-limited settings.

Keywords: *Internet of Things (IoT), Healthcare Monitoring, Body Temperature, DS18B20, NodeMCU, 128x64 LCD, Blynk Platform, Mista.io API, Remote Patient Monitoring, Nyarugenge Hospital, Healthcare Technology, SMS Notifications, Real-Time Data.*

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I. INTRODUCTION

This study presents an Internet of Things (IoT)-based healthcare monitoring system designed to improve patient care by continuously monitoring vital health indicators such as body temperature and heart rate. The system integrates sensors like the DS18B20 for temperature measurement and a heartbeat sensor, with real-time data displayed on a 128x64 LCD screen and remotely monitored through the Blynk platform. The NodeMCU ESP8266 microcontroller powers the system, enabling seamless data collection and transmission. Additionally, the system includes an alert mechanism via the Mista.io API, which sends SMS notifications to doctors when critical thresholds are exceeded, ensuring prompt medical intervention. By addressing the challenges of healthcare monitoring in resource-limited settings, this IoT-based solution offers an affordable, efficient, and scalable approach to improving healthcare delivery, preventing diseases linked to unhealthy lifestyles, and enhancing patient safety through timely interventions.

II. LITERATURE REVIEW

➢ *Introduction to IoT in Healthcare*

The Internet of Things (IoT) in healthcare refers to an interconnected ecosystem involving medical devices, sensors, and applications that collect and analyze patient data in real-time. IoT enables continuous monitoring of patients outside traditional hospital settings, reducing the need for frequent visits and improving disease management, early detection, and personalized treatment. This technology enhances healthcare delivery by enabling more precise and efficient patient monitoring and personalized care. (Kumar & Gupta, 2018)

➢ *Key Applications of IoT in Healthcare*

- *Heartbeat Monitoring:*

IoT-based systems use wearable or non-invasive sensors to monitor heart rate in real-time, offering a dynamic overview of a patient's cardiac health. These systems provide early alerts for irregular heart rhythms and stress levels, which is especially helpful for patients with chronic conditions, reducing the need for in-hospital care. (S. M., 2018)

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- *Temperature Monitoring:*

Body temperature is a critical health indicator. IoT-enabled temperature monitoring systems, such as those using DS18B20 sensors, offer continuous and accurate tracking of a patient's temperature. This data is crucial for diagnosing conditions like infections or fevers. Cloud integration helps healthcare providers track trends and respond swiftly to any abnormalities. (Khan, 2021)

- *Cloud-Based Health Monitoring:*

Cloud technologies are essential in IoT-based healthcare systems, offering secure data storage, real-time monitoring, and predictive analytics. These platforms reduce the need for extensive on-site infrastructure, increase accessibility, and improve collaboration among healthcare professionals. (Ahmadi)

➢ *Core Components of an IoT Healthcare System*

- *Sensors:*

Devices like heartbeat and temperature sensors continuously monitor patient vitals. These sensors send real-time data to processing units (e.g., NodeMCU microcontroller) for analysis and display.

- *Microcontroller (NodeMCU ESP8266):*

The NodeMCU is the primary processing unit that collects data from the sensors and communicates with cloud platforms for real-time monitoring and alerting. Its Wi-Fi capabilities allow seamless integration into the IoT system.

- *Alerting Systems:*

Alerts are triggered by deviations in vital signs (e.g., irregular heart rate or temperature). The system notifies caregivers or medical professionals to enable timely interventions.

- *Cloud Platforms (e.g., Blynk):*

IoT healthcare systems rely on cloud platforms for data storage, visualization, and remote monitoring. Blynk, for instance, allows healthcare professionals to monitor patients from anywhere via mobile or web applications.

➢ *Practical Tools in the System*

- *LCD Screens:*

Local displays, like the 128x64 LCD, show real-time health data, including temperature and heart rate. These screens provide easy access to critical health information at the point of care.

- *SMS Gateway (Mista.io):*

This component sends SMS alerts to healthcare professionals when critical thresholds are exceeded, ensuring timely responses even without internet access.

➢ *Communication Protocols*

- *MQTT:*

The Message Queuing Telemetry Transport (MQTT) protocol is used to transfer data between devices in an IoT ecosystem. This lightweight, low-overhead protocol ensures efficient data communication even in environments with limited bandwidth. MQTT supports real-time health monitoring and facilitates reliable data exchange between sensors, cloud platforms, and user interfaces. (Al-Fuqaha, 2023)

➢ *Theoretical Framework*

- *Systems Theory:*

The interconnectedness of IoT components (sensors, cloud platforms, microcontrollers) ensures efficient patient monitoring and improves healthcare delivery. (Bertalanffy, 1968)

- *Technology Acceptance Model (TAM):*

The success of IoT in healthcare relies on user acceptance, which is influenced by the system's perceived usefulness and ease of use (Davis, 1989).

- *Diffusion of Innovation Theory (DOI):*

The adoption of IoT technologies in healthcare settings depends on their perceived advantages, ease of integration, and effectiveness in improving patient care (Rogers, 2003).

- *IoT Architecture Framework:*

IoT systems are structured into perception, network, and application layers. The perception layer includes sensors (e.g., heart rate, temperature); the network layer involves data transmission (Wi-Fi, cloud platforms); and the application layer consists of interfaces for remote monitoring (LCD screens, mobile apps).

➢ *Empirical Findings*

- *Global Implementation of IoT in Healthcare:*

IoT has revolutionized healthcare globally, improving patient outcomes, reducing readmissions, and enhancing operational efficiency. Studies show a 30% reduction in hospital readmissions for cardiac patients due to continuous monitoring (Smith, 2023).

- *Accuracy of IoT-Based Monitoring:*

IoT systems offer significantly higher accuracy (98%) in detecting irregular heart rhythms compared to traditional methods (85%) due to continuous real-time data collection and analysis (Johnson, 2023).

- *User Acceptance:*

Surveys indicate that 78% of patients feel more secure with continuous IoT monitoring, while 82% of healthcare providers report increased efficiency in workflows due to automated data collection and real-time updates (Brown, 2021).

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III. RESEARCH DESIGN AND METHODOLOGY

➢ *Research Design*

This study employed a mixed-methods approach, integrating both qualitative and quantitative research methods to provide a comprehensive analysis. Data were gathered using questionnaires, interviews, and a review of existing literature. The relationship between independent variables (heartbeat and body temperature) and the dependent variable (patient health status) was explored using predictive analysis. The qualitative method focused on collecting detailed information through interviews and open-ended questions, while the quantitative approach used statistical techniques to identify patterns and trends. This combination ensured the validity of the results and helped in designing an IoT-based monitoring system tailored for Nyarugenge Hospital.

➢ *Study Population*

The study population consists of individuals directly involved in patient care in the intensive care unit (ICU) at Nyarugenge Hospital, including doctors, nurses, patients, and caregivers, totaling 2025 individuals. A sample was randomly selected for the study. Data was collected from 15 individuals, selected through a simple T-test, to represent the larger population. This sample group includes patients, nurses, and caregivers who are central to the study.

➢ *Sampling*

The sample was selected to adequately represent the target population. The sample size of 334 was determined using the formula n=N1+N(e)2n = \frac{N}{1 + N(e)^2}n=1+N(e)2N, where NNN is the total population, and eee is the margin of error (5%). This formula resulted in a sample of 334 respondents, including 650 caregivers, 1325 patients, 12 doctors, and 38 nurses.

➢ *Data Gathering Techniques and Equipment*

Secondary data was collected through literature reviews, medical reports, published research, and healthcare system documentation, providing both qualitative and quantitative insights into IoT applications in healthcare and remote patient monitoring. Case studies of similar IoT-based systems and expert opinions were also used. Data from Nyarugenge Hospital was supplemented by research on other healthcare systems and their challenges.

➢ *Documentation*

Relevant information was gathered from official documents, reports, and publications related to Nyarugenge Hospital and similar healthcare systems. These documents served as primary sources of secondary data.

➢ *Internet Research*

Online resources, including websites and discussion forums, were utilized to gather additional information. This approach was essential for understanding how intensive care units operate in similar settings, such as Nyarugenge Hospital.

➢ *Interviews*

Interviews with healthcare professionals, patients, and caregivers provided valuable insights into their experiences with current monitoring systems. These interactions helped shape the study's conclusions.

➢ *Observation*

The study also included direct observations of nursing practices, particularly focusing on the integration of ICU systems aimed at reducing human error and improving patient care.

➢ *Data Processing*

A letter of reference from the University of Kigali permitted the researcher to collect data. Self-administered questionnaires were distributed to Nyarugenge's healthcare professionals and patients. Data was gathered using sensors, microcontrollers, buzzers, and GSM modules, with programming performed in C language.

➢ *Data Analysis*

The IoT-based system at Nyarugenge Hospital collects and processes real-time health data (heartbeat and body temperature) using sensors and transmits it via NodeMCU to a central database. Statistical methods are applied to identify patterns, trends, and anomalies. Data visualization is provided through the Blynk platform, and alarms are used to notify healthcare providers of any irregularities in patient health status.

➢ *Quantitative Data Analysis*

Data collected through surveys will be organized, coded, and structured for analysis. The Arduino Uno microcontroller is used to upload the processed data, which is then displayed on an LCD screen for healthcare providers to monitor. The system also sends alerts via GSM modules to notify doctors or nurses when abnormal readings are detected.

➢ *Limitations*

A key limitation of this study is its scope—data was collected from a single hospital, Nyarugenge Hospital. Ideally, the study would have included more diverse locations across Africa, but constraints of time and resources prevented this. Additionally, the vast number of patients relative to healthcare staff makes it challenging to monitor all patients simultaneously.

➢ *Ethical Considerations*

The study adhered to ethical guidelines, ensuring that all participants were treated with respect and their confidentiality maintained. No participant was held accountable for their responses, and all data collected was protected. The ethical framework guiding this research emphasized honesty, respect, and integrity in the data collection process (Cohen, 2017).

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➢ *Conceptual Flamework*

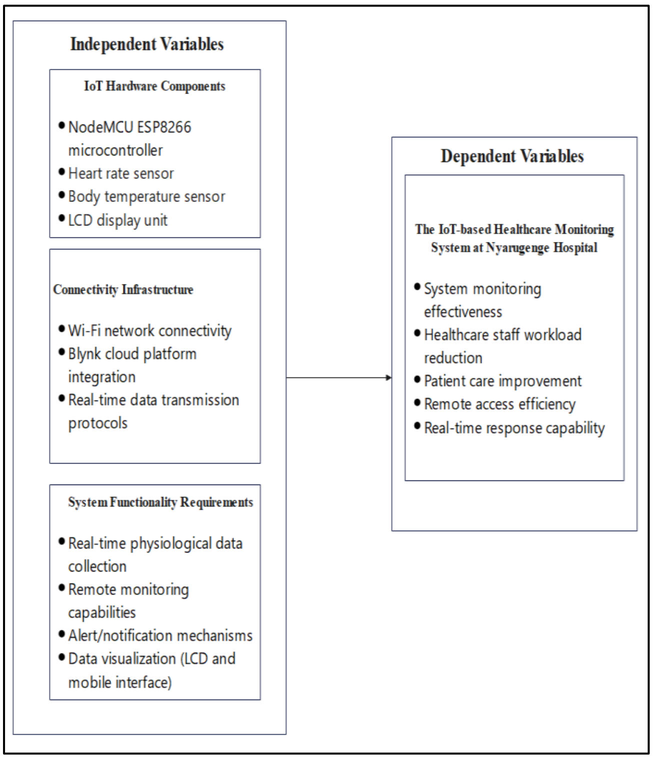

Fig 1 Independent Variable and dependent Variable
Source: Own drawing, 2025

IV. PRESENTATION AND ANALYSIS OF RESEARCH FINDINGS

➢ *System Overview*

The study looked at how an IoT-based system can be developed using a NodeMCU ESP8266 microcontroller with heartbeat and temperature sensors. This system helps to monitor patients' heart rate and body temperature in real time and sends the data to a cloud platform for doctors and nurses to check.

➢ *How It Works*

The IoT-based healthcare monitoring system works by continuously tracking a patient's vital signs, including heart rate and body temperature, through sensors connected to the NodeMCU ESP8266 microcontroller. This microcontroller is chosen for its ease of Wi-Fi connectivity and low power consumption. The system first measures the patient's temperature and heartbeat, then sends the data to the Blynk cloud server for remote monitoring while also displaying it locally for real-time observation.

The system constantly checks whether the recorded data exceeds safe thresholds. If critical values are detected, such as abnormal heart rate or temperature, an alert is sent to the physician via the Mista.io SMS gateway. If the data is within normal limits, the system continues monitoring until it is manually stopped. This process ensures continuous patient monitoring and rapid response in case of emergencies.

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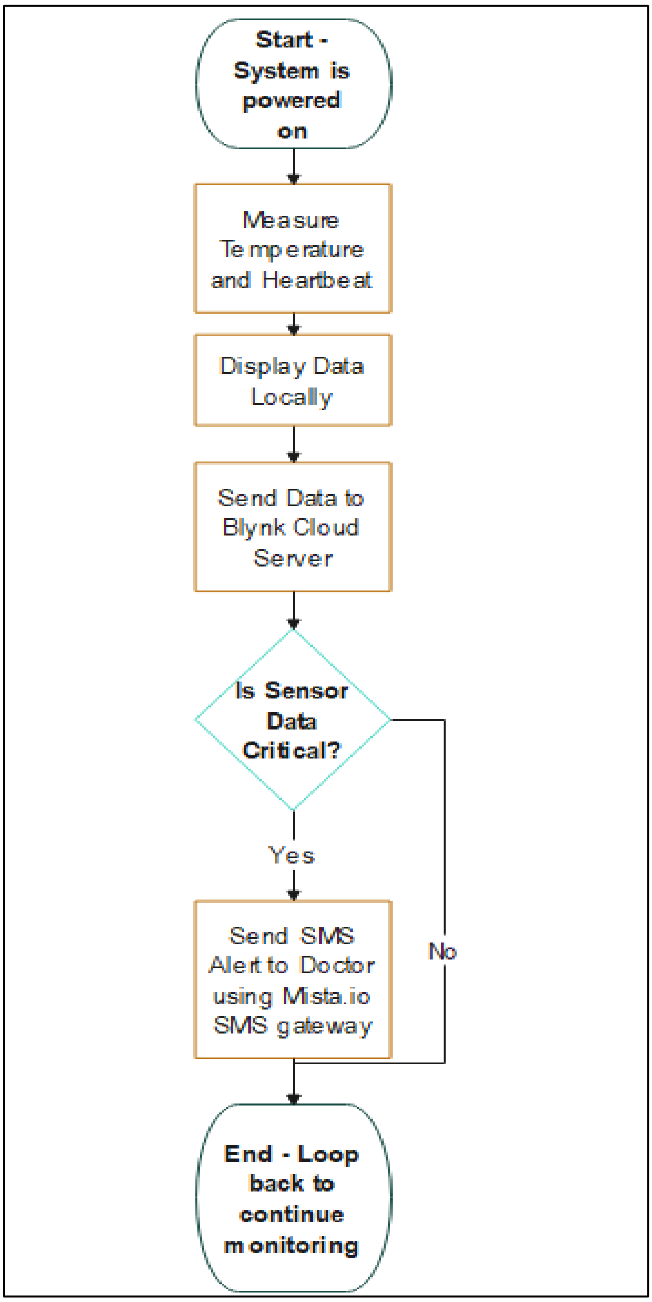

Fig 2 flow chart
Source: Own drawing, 2025

The extended version of the IoT-based healthcare monitoring system tracks a patient's vital signs using a microcontroller connected to a temperature sensor and a heartbeat sensor. The microcontroller processes the data, displays it in real-time, and sends it to the Blynk cloud server for remote monitoring. When critical readings are detected, the system alerts a physician through the Mista.io SMS gateway, ensuring prompt medical intervention. This setup enables healthcare providers to monitor patients remotely and respond quickly to emergencies, enhancing patient care and safety.

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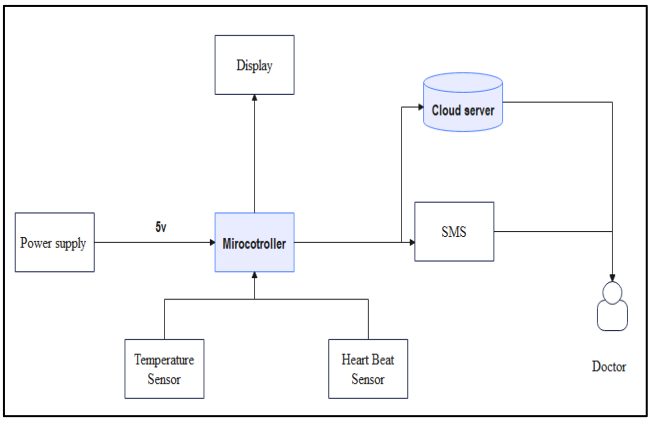

Fig 3 Block Diagram
Source: Own Drawing, 2025

The expanded IoT-based system for monitoring temperature and heartbeat is illustrated in the circuit diagram. The NodeMCU microcontroller serves as the central hub, connecting various components to collect, process, and display real-time data. The heartbeat sensor (HB1) monitors cardiac activity, while the DS18B20 digital temperature sensor tracks body temperature and transmits this information to the NodeMCU. The temperature and heart rate data are displayed on a 128x64 LCD screen connected via I2C. The system includes a SIM900 GSM module, powered by a 5V battery (BAT1), to enable remote communication by sending SMS alerts when vital signs exceed predetermined thresholds. A switch (SW1) allows for manual resetting or powering of components. This system enhances healthcare by providing continuous monitoring and enabling remote alerts to doctors, improving the response time for critical health conditions.

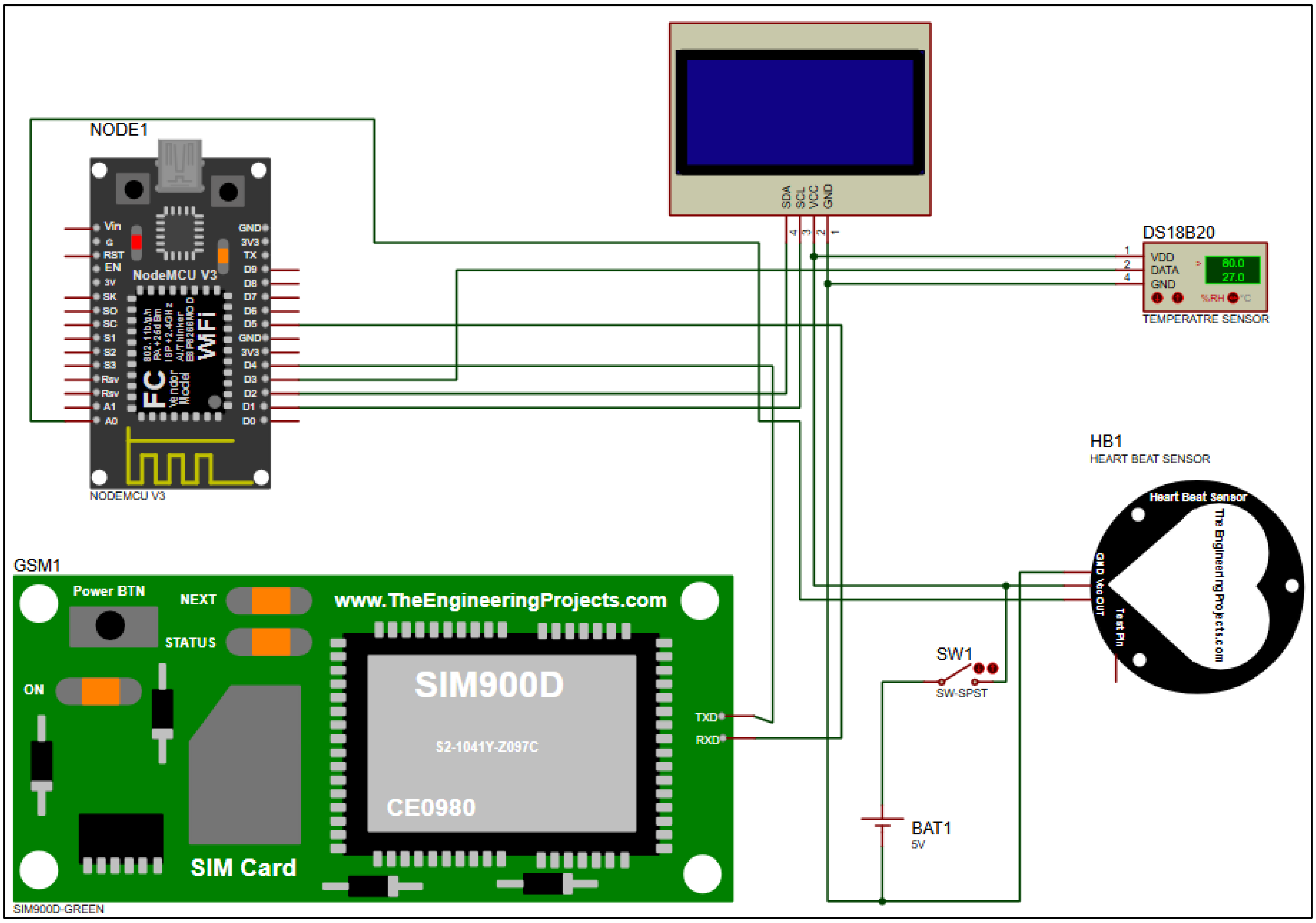

Fig 4 Circuit Diagram
Source: Own Drawing, 2025

➢ *Challenges in System Development:*

Developing an IoT-based healthcare monitoring system that integrates real-time data collection, processing, and remote monitoring comes with several challenges. Key issues include poor internet connectivity, data security risks, and sensor errors. Solutions such as data encryption, backup connections, and regular sensor calibration are recommended to address these problems.

➢ *Connecting LCD Display and Blynk Cloud for Remote Monitoring:*

The system leverages the LCD display and Blynk Cloud to enable real-time monitoring and remote access to patient data. The LCD display plays a crucial role in immediate, on-site monitoring, allowing healthcare staff to view patients' vital signs without needing an internet connection. This helps ensure quick intervention if a patient's condition changes.

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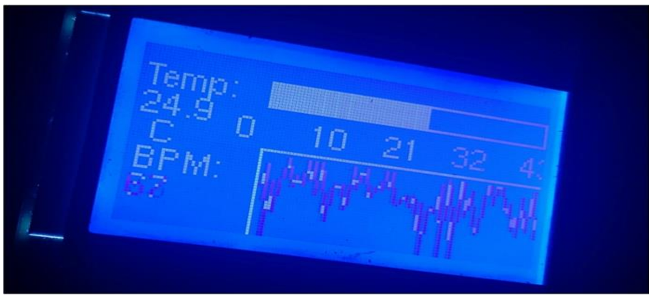

Fig 5 Sensors Graph
Source: Own Capture with Mobile Phone (Camera), 2025

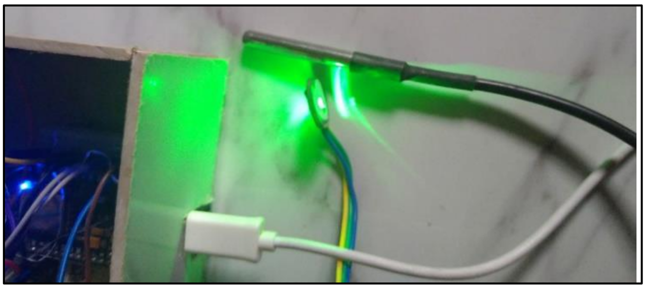

Fig 6 Heartbeat Sensor
Source: Own Capture with Mobile Phone (Camera), 2025

The system continuously monitors the patient's body temperature using a sensor, sending the data to the NodeMCU for analysis. If the temperature falls below 36°C (hypothermia) or exceeds 38°C (fever), the system triggers an alert. A temperature of 39°C or higher indicates a fever, prompting an urgent notification to the attending doctor with the patient's name and current temperature. The heartbeat sensor also tracks the patient's heart rate, sounding an alert if it falls below 60 beats per minute (bradycardia) or exceeds 100 beats per minute (tachycardia). If the heart rate drops to 50 beats per minute, the NodeMCU detects bradycardia and sends an SMS to the doctor via the GSM module or Mista.io, ensuring a quick response for immediate medical

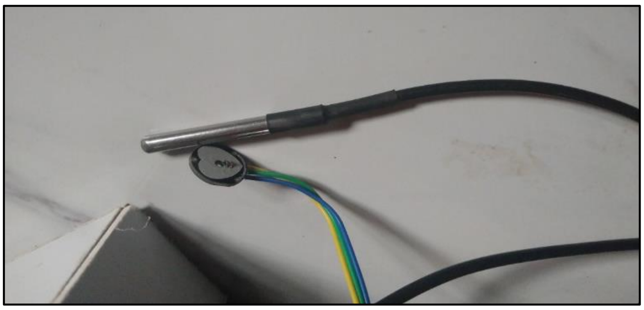

Fig 7 Temperature Sensor
Source: Own Capture with Mobile Phone (Camera), 2025

The DS18B20 is a digital temperature sensor that uses a thermistor to measure temperature and uses its internal processing unit to transform the data into a digital output. Using the 1-Wire protocol, it just requires one data line (plus ground) to connect to the NodeMCU. With an accuracy of ±0.5°C in the range of -10°C to +85°C, the sensor provides high-precision temperature measurements, usually in the range of -55°C to +125°C.The sensor provides data to the NodeMCU for processing after continually taking the patient's body temperature.

If temperature falls below 36°C (hypothermia) or climbs above 38°C (fever), the device will sound an alert. If a hospital patient's body temperature is 39°C, the NodeMCU interprets this as a fever. Through the GSM module, the system provides the attending physician with the patient's name and current temperature in order to ensure rapid medical assistance.

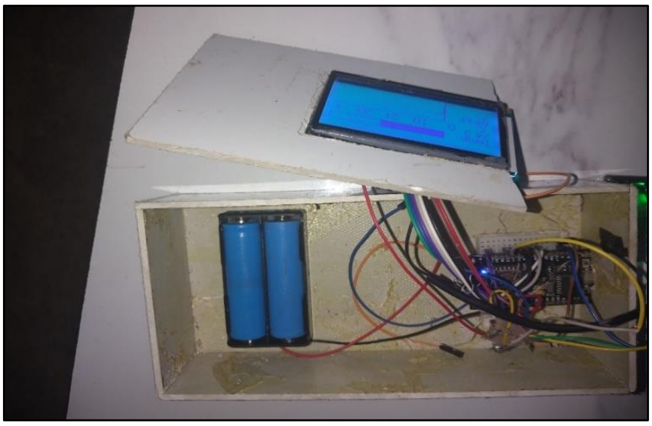

Fig 8 Battery
Source: Own Capture with Mobile Phone (Camera), 2025

The battery (BAT1) plays a critical role in powering the IoT-based heartbeat and temperature monitoring system. It ensures a steady 5V DC power supply to all components, including the NodeMCU, sensors (DS18B20 and heartbeat sensor), LCD display, and GSM module, which is essential for the system's operation. This is particularly important in situations where direct power sources may be limited, such as during blackouts or in remote locations. The battery also contributes to the system's portability, allowing it to be used across different hospital settings, such as various wards or patient rooms. It ensures continuous monitoring, even in case of power interruptions, maintaining reliable data collection and processing. The battery also supports the GSM module, ensuring that SMS notifications are sent promptly, even if the primary network is weak. This backup power system enhances real-time patient monitoring and care, especially in emergency situations.

Fig 9 Internal Circuit
Source: Own Capture with Mobile Phone (Camera), 2025

The ESP8266 is the key microcontroller in the IoT-based heartbeat and temperature monitoring system, seamlessly integrating sensor data collection, processing, and display. It collects real-time data from temperature and heart

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rate sensors connected to its GPIO pins, using graphical libraries like U8g2 to display the data on an LCD screen. The microcontroller processes the data to determine vital signs, such as body temperature and BPM, and uses its built-in Wi-Fi to transmit the data to cloud servers or mobile apps for remote monitoring. By linking the sensors, LCD, and internet, the ESP8266 ensures continuous, accurate, and real-time monitoring of patient vitals, enhancing the overall efficiency and responsiveness of the healthcare system at Nyarugenge Hospital.

Fig 10 Lcd Screen With Sensor Values
Source: Own Capture with Mobile Phone (Camera), 2025

The LCD screen (128x64) plays a vital role in the IoT-based heartbeat and temperature monitoring system by providing real-time visual feedback on a patient's critical signs, such as body temperature and heart rate. It displays both numerical values and graphical patterns, helping medical professionals monitor the patient's condition and identify any irregularities. If abnormalities like high body temperature or an irregular pulse are detected, the screen can display alerts, prompting immediate medical action. Additionally, it serves as the user interface, enabling staff to quickly analyze data and ensure proper system functioning, which enhances decision-making and patient monitoring.

Blynk Cloud facilitates remote monitoring by enabling doctors and nurses to access patient data in real time, regardless of location. This allows healthcare professionals to make quick, informed decisions and detect health issues early, ultimately improving patient safety through proactive care.

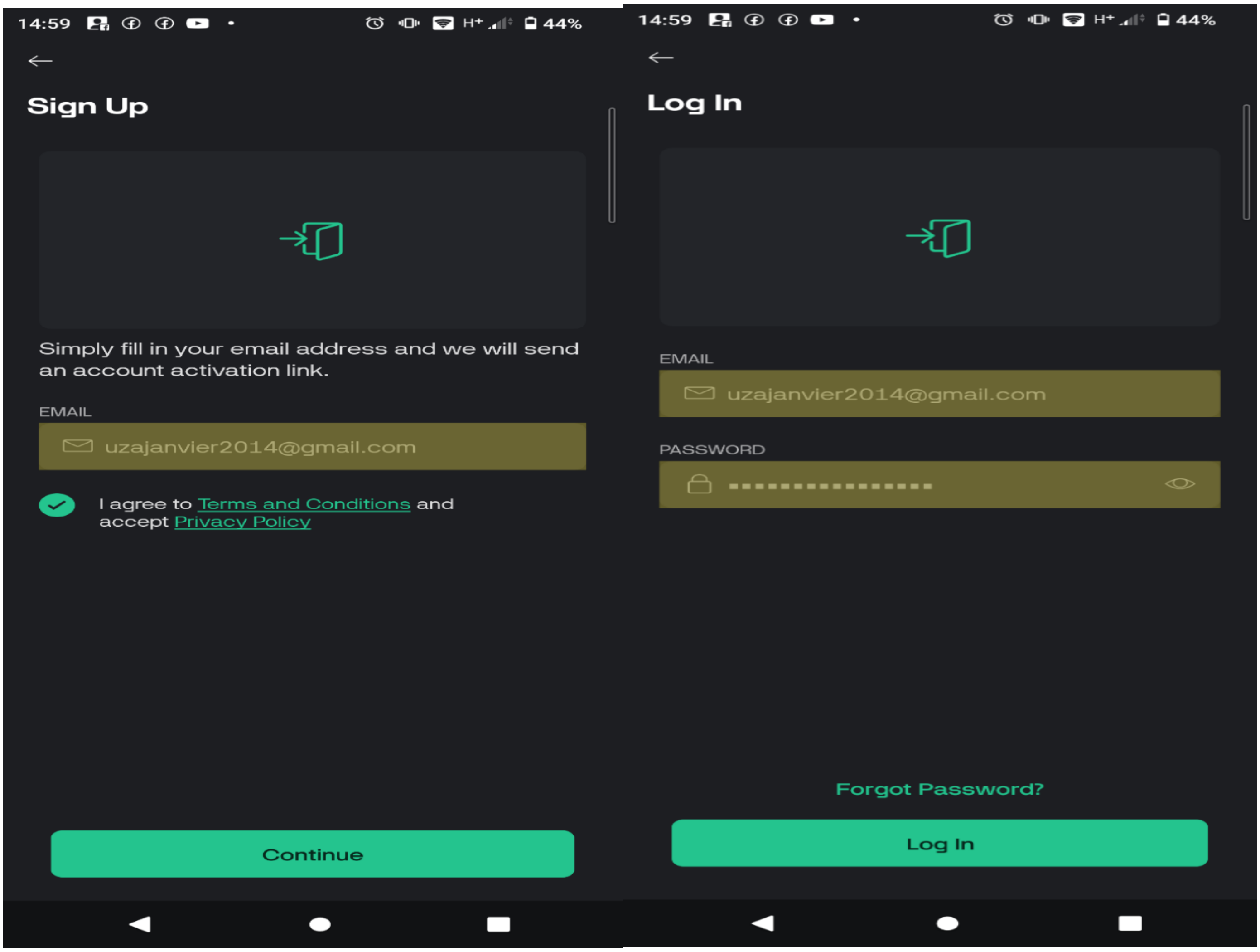

Fig 11 Blynk Creating Account
Source: Own Capture with Screenshot (Phone), 2025

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To enable remote monitoring of the IoT-based heartbeat and temperature monitoring device, users must first register and log in to the Blynk app. By creating an account, healthcare professionals can connect the NodeMCU, sensors, and LCD display to Blynk using an authentication token, ensuring secure access. Once logged in, users can monitor real-time patient data such as body temperature and heart rate. The system also sends alerts if these metrics exceed preset thresholds, enabling authorized personnel to intervene promptly. This remote access capability helps ensure timely medical responses while maintaining patient privacy and safety.

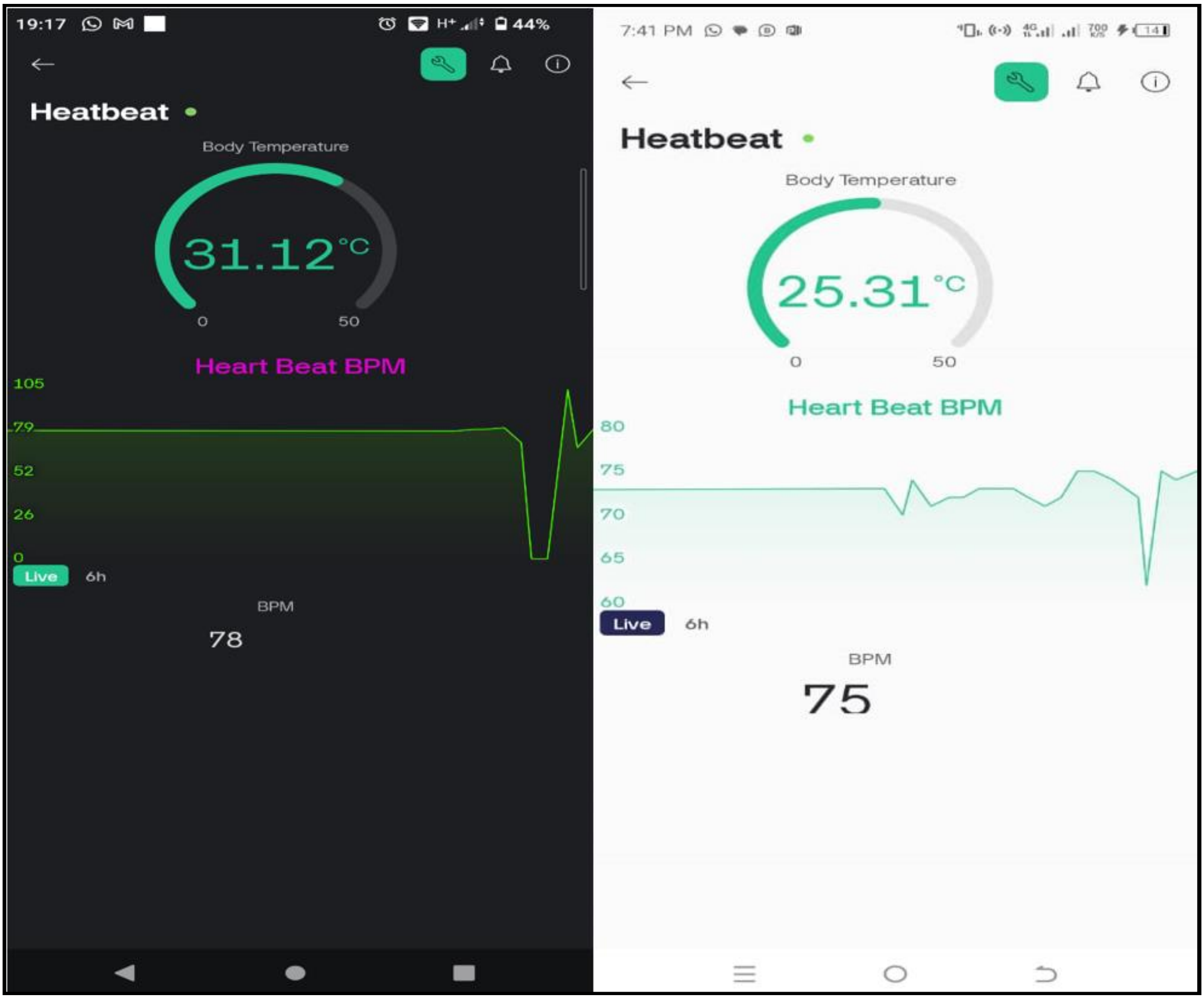

Fig 12 Blynk Graphs
Source: Own Capture with Screenshot (Phone), 2025

The system tracks and displays important metrics such as body temperature (e.g., 25.31°C) and heart rate (e.g., 75 BPM) through a user-friendly smartphone interface. It integrates IoT modules like the ESP8266 and sensors, enabling real-time monitoring of critical health indicators, which helps medical practitioners access vital information quickly and accurately, ultimately improving patient care.

However, cloud-based monitoring faces challenges such as slow data transmission, security risks, and the need for a stable internet connection. To address these issues, researchers recommend secure encryption, backup storage, and reliable internet services.

IoT-based systems have significantly improved patient monitoring by allowing doctors and nurses to track patients more efficiently, reducing the need for manual checks, which saves time and enhances productivity. Proteus, a simulation tool, also aids in testing and debugging code created with the Arduino IDE. It allows developers to simulate system performance, troubleshoot issues, and ensure the reliability of the system before physical implementation, making it an essential tool for prototyping and optimizing IoT healthcare solutions.

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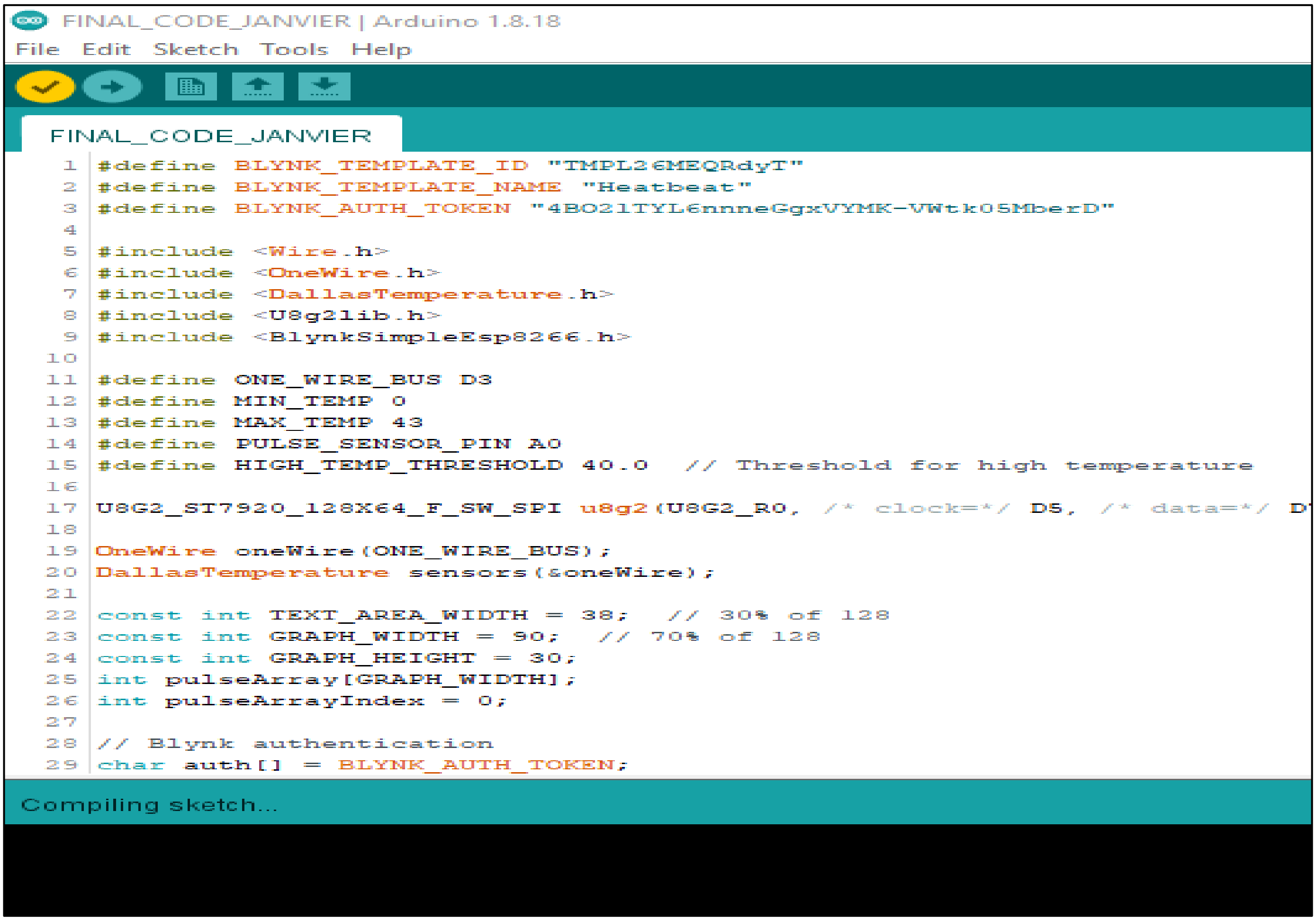

Fig 14 Arduino Ide
Source: Own Capture with Screenshot (Computer), 2025

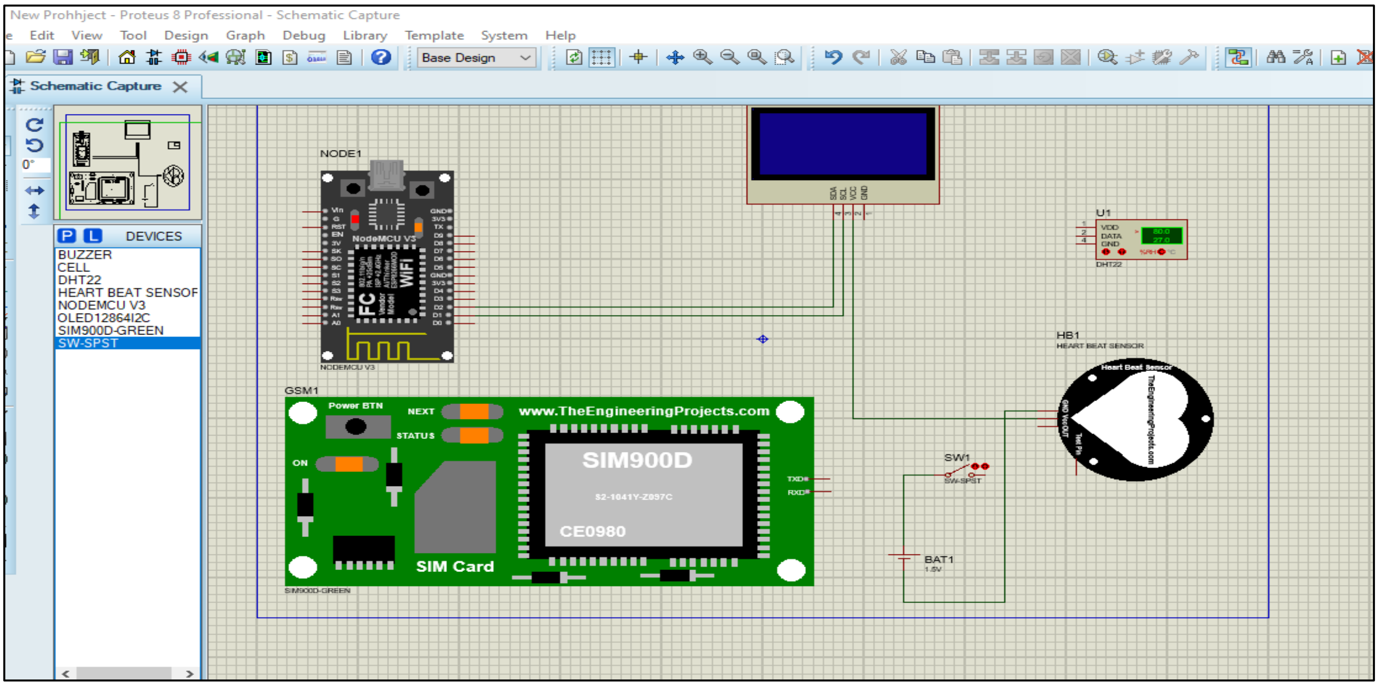

Fig 15 Proteus Software
Source: Own Capture with Screenshot (Computer), 2025

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Proteus played a key role in the development of the new system by providing a platform for circuit and component modeling, as well as virtual testing before physical implementation. It enabled the design of the schematic layout, which includes the NodeMCU microcontroller, sensors (DS18B20 and heartbeat sensor), LCD display, and GSM module. This virtual simulation allowed users to model the system's behavior and test its functionality without the need for immediate physical hardware setup. It helped ensure the system's operation, verify the accuracy of connections, and confirm that the logic worked as expected.

V. CONCLUSION

In summary, Nyarugenge Hospital's IoT-based monitoring system has proven to be a reliable and effective tool for continuously tracking patients' body temperatures and heart rates. By utilizing an LCD screen and the Blynk cloud platform, healthcare professionals can remotely monitor patients, enabling quick responses to emergencies and improving patient safety. The system reduces manual monitoring tasks, freeing up medical staff to focus on other critical duties, while also enhancing the accuracy of patient care.

This study highlights the potential of IoT technologies to transform healthcare, particularly in resource-limited settings, by offering innovative solutions to gaps in patient care. The system demonstrates the value of smart technologies in supporting both patients and medical staff, setting the stage for future advancements in healthcare technology.

RECOMMENDATIONS

- *Expansion:*

Extend the IoT-based monitoring system to additional departments and wards at Nyarugenge Hospital to improve patient care and coverage.

- *Training:*

Regular training for healthcare staff is recommended to optimize system usage and ensure accurate data interpretation. Training should also include emergency response protocols based on system alerts.

- *System Enhancement:*

Future updates should consider adding more sensors, such as those measuring respiration rate, blood pressure, and oxygen saturation, to provide a more comprehensive view of patient health.

- *Data Security:*

Focus on strengthening data security by implementing encryption and access control measures to protect patient information, ensuring compliance with healthcare privacy regulations.

- *Long-Term Research:*

Conduct longitudinal studies to assess the long-term impact, challenges, and cost-effectiveness of IoT monitoring systems, providing valuable insights for future improvements and broader adoption.

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