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IoT Based Patient Health Monitoring System

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ABSTRACT: Healthcare systems today require smarter and more efficient methods to continuously observe patient conditions without the need for constant hospital visits. This project introduces an IoT Based Patient Health Monitoring System that enables real-time tracking of important physiological parameters. The system is designed to measure values such as body temperature, heart rate, and blood oxygen saturation using appropriate biomedical sensors. The sensed data is processed through a microcontroller unit and transmitted using IoT communication technology to an online platform for remote access. Medical professionals and caregivers can monitor the patient's health status from any location, which helps in early detection of abnormal conditions. In case of irregular readings, the system can generate alerts to ensure immediate response.

By reducing the dependency on manual monitoring and frequent hospital visits, the proposed system offers a more convenient and cost-effective healthcare solution. It is particularly useful for continuous observation of elderly individuals and patients requiring long-term medical attention. This approach enhances patient safety, improves monitoring accuracy, and supports modern healthcare requirements.

KEYWORDS: Internet of Things (IoT), Patient Health Monitoring, Automated Oxygen Supply, SpO2 Monitoring, Vital Signs Tracking, Relay Control Mechanism, Remote Healthcare, Emergency Alert System.

I. INTRODUCTION

In standard medical environments, keeping track of a patient's health usually requires the continuous physical attention of doctors and nurses. Vital metrics like body temperature, pulse rate, and blood oxygen saturation (SpO2) are typically recorded by hand at specific intervals using regular hospital devices. Even though this manual approach yields precise medical information, it demands heavy manpower and constant oversight. Consequently, it falls short for continuous 24/7 monitoring, particularly in home-care situations or hospitals facing a shortage of medical staff.

A major challenge in managing critical care is the abrupt and unforeseen decline in heart or lung function. For patients confined to their beds or those with long-term respiratory diseases, a rapid decrease in oxygen levels can cause severe damage or death if not treated immediately. Traditional methods that depend on routine physical check-ups frequently lead to dangerous delays in medical care. Hence, there is a pressing need for a smart, self-operating system capable of non-stop health evaluation and triggering initial life-saving measures even prior to a physician's arrival.

To solve these problems, this project introduces an automated, IoT-driven health tracking and emergency reaction framework. By integrating non-invasive sensory equipment with embedded microcontrollers, this architecture seamlessly observes critical physiological metrics and handles emergency protocols. Wearable or bedside modules equipped with temperature, heart rate, and SpO2 sensors continuously analyze the patient's biological state to spot any unusual fluctuations the moment they occur.

To solve these problems, this project introduces an automated, IoT-driven health tracking and emergency reaction framework. By integrating non-invasive sensory equipment with embedded microcontrollers, this architecture seamlessly observes critical physiological metrics and handles emergency protocols. Wearable or bedside modules equipped with temperature, heart rate, and SpO2 sensors continuously analyze the patient's biological state to spot any unusual fluctuations the moment they occur.

Beyond mere continuous data recording, this setup features an automatic life-preservation function that delivers prompt medical aid. A central microcontroller evaluates the sensor outputs and syncs them with an IoT cloud network. Whenever a patient's oxygen saturation dips below a predefined secure limit, the processor immediately activates a relay module. This action autonomously switches on an oxygen delivery pump to stabilize the patient, eliminating the need for manual operation. At the same time, internet-based alerts and live health statistics are sent directly to the smartphones of healthcare providers and family members. By taking care of both constant observation and immediate emergency intervention, this proposed model significantly cuts down medical reaction times, lessens the burden on human workers, and guarantees better protection for patients.

II. BACKGROUND

Healthcare is a critical sector that focuses on maintaining and improving the health of individuals. Monitoring vital health parameters such as body temperature, heart rate, and blood oxygen level is essential for diagnosing and managing various medical conditions. With the increasing population and the rise in chronic diseases, the need for efficient and continuous patient monitoring systems has become more important than ever.

One of the major challenges in traditional healthcare systems is the lack of continuous monitoring. In many cases, patients are observed only during hospital visits or scheduled checkups. This approach does not provide real-time information about the patient's condition and may lead to delays in identifying serious health issues. Continuous monitoring is especially important for elderly individuals and patients suffering from long-term illnesses.

Another significant issue is the difficulty in providing timely medical assistance during emergencies. Sudden changes in health parameters, such as a drop in oxygen level or irregular heart rate, may not be immediately detected in conventional systems. This delay can increase the risk of complications and reduce the effectiveness of treatment. Therefore, there is a need for systems that can monitor patient health continuously and provide instant alerts.

Traditional health monitoring methods often rely on manual measurements using standalone devices. These methods require the presence of medical personnel and may not be convenient for home-based care. In addition, the collected data is not always stored or shared effectively, limiting its usefulness for long-term analysis and decision-making.

Recent advancements in embedded systems and communication technologies have enabled the development of smart healthcare solutions. The Internet of Things (IoT) plays a major role in this transformation by allowing devices to connect, collect, and exchange data in real time. Sensors capable of measuring physiological parameters can be integrated with microcontrollers to create intelligent monitoring systems.

These systems can transmit patient data to cloud platforms, where it can be accessed by doctors and caregivers remotely. Real-time data transmission helps in early detection of abnormal conditions and supports quick medical decisions. Alert mechanisms can also be implemented to notify users when health parameters exceed normal limits.

The IoT Based Patient Health Monitoring System is developed based on these technological advancements. The proposed system integrates biomedical sensors, a microcontroller, and IoT communication modules to continuously monitor patient health. By combining real-time data acquisition with remote monitoring capabilities, the system improves healthcare efficiency, reduces manual effort, and ensures better patient safety.

III. RELATED WORKS

Many researchers have focused on improving patient health monitoring and automated medical response technologies by integrating biosensors, embedded systems, and smart communication techniques. Some important related research works are summarized below:

1. Sensor-Based Vital Sign Monitoring Systems:
Several researchers have developed continuous health monitoring systems using biomedical sensors to measure critical parameters such as body temperature, heart rate, and blood oxygen saturation (SpO_2). These systems analyze physiological characteristics to identify abnormal health conditions in real-time. The studies demonstrated that continuous sensor-based monitoring can provide faster and more reliable results compared to traditional periodic manual checking by nursing staff, thereby reducing the risk of unnoticed health deterioration.

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2. IoT-Based Remote Patient Monitoring:
Recent studies have proposed IoT-enabled patient monitoring systems where sensor data is transmitted to cloud platforms for analysis and secure storage. These systems allow doctors and caregivers to remotely monitor patient parameters from anywhere using mobile applications or web dashboards. The research highlighted that IoT technology can significantly improve healthcare accessibility, enhance transparency in patient records, and reduce the routine workload on hospital staff.

3. Automated Medical Actuation Using Microcontrollers:
Another research work introduced a microcontroller-based automated response system designed to provide immediate medical assistance without human intervention. Similar to automated vending systems, these setups use relays, pumps, and valves to administer essential life support, such as oxygen or intravenous fluids, based on real-time sensor readings. The results showed that automated actuation systems can drastically reduce response times during critical emergencies and provide immediate life-support before medical personnel arrive.

4. Wearable Health Tracking Devices:
Some researchers have developed wearable IoT systems to provide continuous, non-invasive health tracking for elderly, post-surgery, and bedridden patients. In these systems, users wear compact, low-power sensor modules that continuously communicate with a central gateway via Wi-Fi or Bluetooth. Such technologies have been successfully implemented to monitor chronic respiratory and cardiac patients, ensuring that high-risk individuals are constantly supervised even in a home-care setting.

5. Intelligent Emergency Alert Systems:
Another area of research focuses on detecting critical health anomalies using threshold-based algorithms to trigger instant emergency alerts. These systems continuously analyze multiple parameters to determine if a patient is entering a critical state, such as hypoxia or sudden cardiac arrest. The results indicate that intelligent alert mechanisms can effectively notify primary caregivers and doctors via SMS, emails, or push notifications, preventing fatal outcomes due to delayed medical attention.

IV. PROPOSED RESEARCH DESIGN AND ARCHITECTURE

The IoT Based Patient Health Monitoring System with Automated Oxygen Supply is specifically designed to enhance the safety, efficiency, and reliability of critical patient care. The traditional dependency on manual monitoring is replaced by a highly responsive, automated closed-loop system. The key features and architectural flow of the proposed system are described below in detail.

1. Continuous Vital Sign Monitoring
The core functionality of the proposed architecture is the real-time, continuous monitoring of a patient's vital signs. The system integrates biomedical sensors, primarily a Pulse Oximeter sensor (like MAX30100/MAX30102) and a highprecision Temperature sensor (like DS18B20 or LM35). The Pulse Oximeter continuously tracks the heart rate (BPM) and blood oxygen saturation levels (SpO2), while the temperature sensor monitors the body heat. These sensors are attached to the patient non-invasively, ensuring continuous data collection without causing discomfort, and helping to identify abnormal physiological changes instantly.

2. Automated Oxygen Actuation System (Relay & Pump Mechanism)
One of the most significant contributions of this architecture is the automated life-support dispensing mechanism. A relay module is interfaced between the central microcontroller and an external medical oxygen pump. The microcontroller is programmed with predefined safe medical thresholds (e.g., SpO2 > 94%). If the sensor detects that the patient's oxygen level has dropped below the critical threshold (hypoxia condition), the microcontroller immediately sends a digital 'HIGH' signal to the relay. This activates the relay switch, which automatically turns on the oxygen pump to supply life-saving oxygen to the patient instantly, bridging the critical gap before a doctor arrives.

3. IoT Cloud Integration and Remote Access
Unlike localized traditional monitoring, this system integrates a Wi-Fi-enabled microcontroller (such as NodeMCU ESP8266 or ESP32) to facilitate Internet of Things (IoT) connectivity. The microcontroller processes the raw analog and digital data from the sensors and transmits it continuously to a dedicated IoT cloud platform (such as ThingSpeak, Blynk, or a custom web server). This architecture allows doctors, nurses, and family members to securely access the patient's real-time health data from any remote location using a smartphone or computer.

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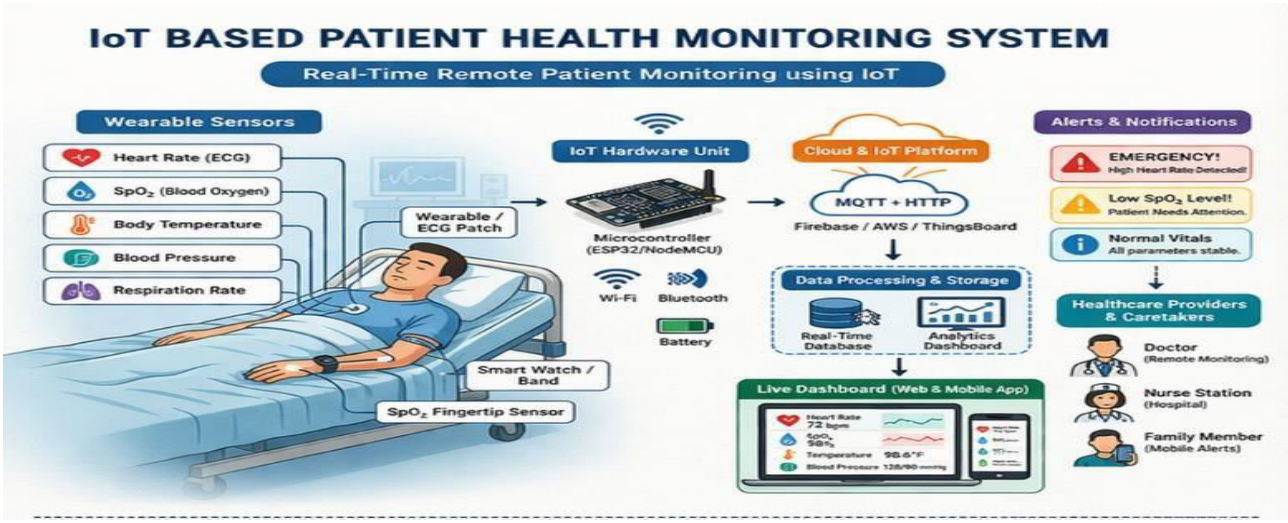
Intelligent Emergency Alert Mechanism
The system is equipped with an intelligent emergency notification architecture. Whenever an abnormal health condition is detected (e.g., sudden spike in heart rate, severe fever, or low SpO2), the system does not just actuate the oxygen pump, but it also triggers a wireless alert. The IoT module instantly pushes an emergency notification, SMS, or email to the registered mobile devices of the primary caregivers and hospital staff. This ensures that the medical team is instantly aware of the patient's deteriorating condition.

4. Real-Time Bedside Display
For immediate local observation, an LCD or OLED display module is integrated into the bedside monitoring unit. It provides a real-time visual representation of the patient's current heart rate, SpO2 levels, temperature, and the operational status of the oxygen pump (ON/OFF). This allows any attending nurse or caregiver in the room to easily understand the patient's condition at a single glance without needing to log into the IoT dashboard.

5. Reduction of Human Intervention and Error
By completely automating the data logging, analysis, and initial emergency actuation (oxygen supply), the proposed architecture drastically minimizes the need for continuous human supervision. This reduction in manual intervention not only reduces the workload on medical staff but also eliminates the chances of human error, such as delayed response times or missed periodic check-ups during night shifts.

6. Scalable System for Smart Hospitals
The modular design of the proposed architecture allows for future scalability.



This single-patient node can be expanded into a multi-bed Smart Hospital Network, where hundreds of such units can be connected to a centralized hospital server. Future enhancements can easily integrate Artificial Intelligence (AI) to predict patient health trends based on the continuous IoT data streams.

V. DATA COLLECTION

Collecting data is an essential part of this project, as it helps in checking how well the patient monitoring system works in real-time conditions. In this system, information is gathered from different sources such as sensors, communication modules, and system operations to understand its accuracy and performance.

1. Physiological Data Collection
The system continuously collects health-related data from the patient using various sensors.
Body Temperature:
The temperature sensor records the patient’s body heat at regular intervals. This helps in identifying unusual temperature changes.
Heart Rate:

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The pulse sensor captures the number of heartbeats per minute. This data is useful for observing variations in heart activity.
Oxygen Saturation (SpO_2):
The sensor measures the level of oxygen present in the blood. This value indicates whether the patient is receiving sufficient oxygen.

2. Condition Evaluation Data
The values obtained from the sensors are used to understand the patient's current health status. Each reading is checked against normal limits to identify whether it is within a safe range or not. This step helps in early detection of health issues.

3. Device Performance Data
Apart from health data, the system also records how the device performs during operation. This includes the time taken to read sensor values, process the data, and update the output. These details help in verifying the efficiency of the system.

4. Communication Data
Since the system sends information to a remote platform, data related to communication is also collected. This includes how quickly the data is sent, whether the transmission is successful, and how stable the connection remains during operation.

5. Alert Response Data
The system is designed to give alerts when any parameter goes beyond normal levels. Information such as how fast the alert is generated and whether it reaches the user correctly is recorded. This ensures the reliability of emergency notifications.

6. Testing Observations
To check the working condition of the system, several test cases are performed. During testing, the following details are noted:
* Values obtained from all sensors
* Accuracy of the readings
* Time required for sending data
* System behavior during abnormal conditions
* Alert generation performance

7. Interpretation of Collected Data
After gathering all the data, it is carefully examined to understand how effectively the system performs. This evaluation helps in confirming whether the system can monitor patient health accurately, send information without delay, and provide alerts when needed.

VI. APPLICATION OF THE INTERNET OF THINGS (IOT) IN THE PROPOSED SYSTEM

The integration of the Internet of Things (IoT) serves as the primary backbone of this automated patient monitoring architecture. By connecting medical sensors and actuation hardware to the internet, IoT transforms traditional, localized medical equipment into a globally accessible, smart healthcare network. The major applications and benefits of IoT within this proposed system are detailed below:

1. Real- Time Remote Monitoring (Telemedicine)
One of the most significant applications of IoT in this project is enabling doctors and primary caregivers to monitor a patient's vital signs from any geographic location. Using a Wi-Fi-enabled microcontroller (such as NodeMCU ESP8266 or ESP32), the continuous data streams from the SpO_2 and temperature sensors are pushed to a cloud server. Medical professionals can seamlessly access this live physiological data through a dedicated web dashboard or mobile application, completely eliminating the necessity of being physically present at the patient's bedside.
2. Instantaneous Emergency Alert Mechanism
IoT plays a life-saving role by facilitating ultra-fast communication during critical medical situations. When the local microcontroller detects that the patient's blood oxygen saturation has dropped below the pre-programmed safe threshold (hypoxia), the IoT module instantly triggers wireless alerts. Push notifications, emails, or SMS messages are

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immediately dispatched over the internet to the registered smartphones of the hospital staff or family members. This ensures a near-zero delay in notifying the concerned individuals about the emergency.

3. Automated Cloud-Based Health Data Logging
Traditional patient monitoring relies heavily on the manual entry of health records by nursing staff, a process that is prone to human error, delays, and data loss. Through IoT integration, every physiological parameter read by the sensors is automatically timestamped and securely stored in a centralized cloud database (such as ThingSpeak, Blynk, or AWS). This continuous logging creates a highly accurate, permanent digital health record that physicians can retrieve and analyze at any time to understand the patient's medical history.

4. Seamless Machine-to-Machine (M2M) Actuation
IoT facilitates intelligent interaction between the sensing unit and the automated hardware response system. In this architecture, the IoT framework allows the central microcontroller to continuously evaluate the incoming sensor inputs and autonomously send digital control signals to the relay module. This seamless M2M communication is exactly what enables the oxygen pump to activate automatically without requiring any human input or manual switch operation.

5. Scalable Smart Hospital Architecture
The application of IoT extends far beyond a single-bed setup. This framework is highly scalable and can be seamlessly implemented across an entire hospital ward or intensive care unit (ICU). Hundreds of individual bedside monitoring nodes can be connected to the centralized hospital Wi-Fi network, streaming data to a single master monitoring station. This allows a small team of nurses to efficiently and accurately monitor a large number of patients simultaneously from a single digital screen.

6. Cost-Effective Home Healthcare Management
For elderly individuals, post-surgery patients, or those suffering from chronic respiratory illnesses, prolonged hospital stays can be financially exhausting. The IoT application allows for the creation of an affordable, automated home-care setup. The patient's vitals are continuously collected and sent to their primary care physician over the internet, providing hospital-grade observation and safety within a comfortable domestic environment.

VII. TRAINING FLOWCHART

The machine learning training process for predictive patient health monitoring involves several systematic stages. This flow enables the system to learn from historical health data and automatically predict critical conditions like sudden hypoxia before they occur.

1. Data Collection
The first step is gathering large amounts of physiological data. Continuous streams of sensor data, including Heart Rate (BPM), SpO2 levels, body temperature, and the operational history of the automated oxygen pump, are collected and securely stored in the IoT cloud server.

2. Data Preprocessing
Raw biomedical sensor data often contains noise, incorrect readings due to patient movement, or missing values. In this stage, the collected data is cleaned, filtered, and organized into a structured format to ensure the ML model learns accurately.

3. Feature Extraction
Important physiological parameters and their variations over time (e.g., the rate of oxygen drop per minute, sustained high body temperature, or abnormal heart rate spikes) are extracted. These critical 'features' act as the primary indicators for training the predictive model.

4. Model Selection
Depending on the objective (e.g., anomaly detection or health condition classification), a suitable machine learning algorithm is selected. Algorithms like Random Forest, Support Vector Machines (SVM), or Deep Neural Networks are highly effective for healthcare predictions.

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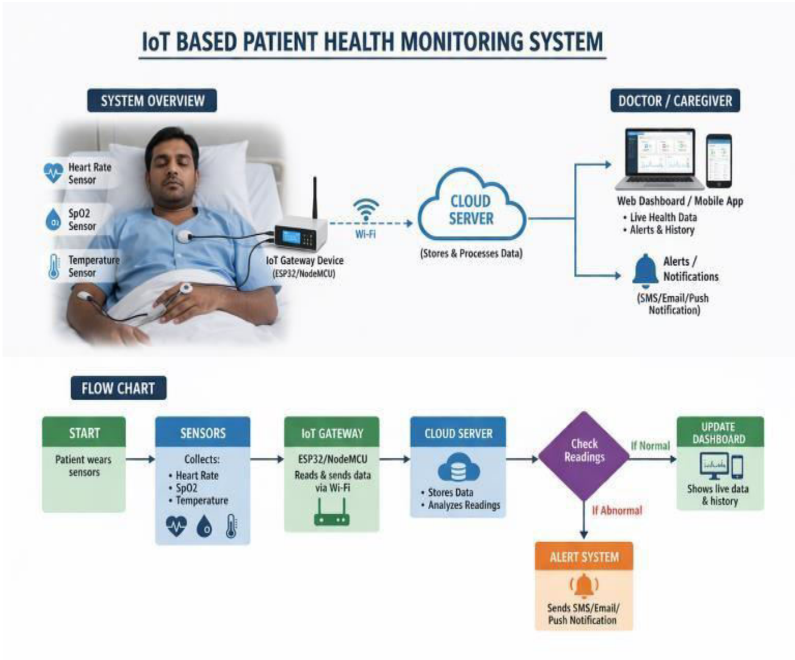
5. Model Training
The selected ML algorithm is trained using the preprocessed historical patient dataset. During this phase, the algorithm learns to identify complex hidden patterns associated with stable health, moderate risk, and highly critical medical conditions.

6. Model Testing
Once trained, the model is tested using a new set of unseen sensor data. This ensures that the algorithm can accurately predict a patient's health status in real-world scenarios without memorizing the training data.

7. Performance Evaluation
The accuracy, sensitivity, and reliability of the trained model are evaluated using standard metrics. In a healthcare system, ensuring a high true-positive rate (correctly identifying a critical emergency) and a low false-positive rate is extremely crucial.



8. Deployment
Finally, the successfully trained and validated ML model is deployed directly into the IoT Cloud Server or the edge gateway (ESP32). Once deployed, it enables the system to make smart, proactive decisions—such as predicting an emergency and alerting doctors before the patient's SpO2 level drops to a fatal threshold.

VIII. TESTING AND VALIDATION

Testing and validation are essential steps to confirm that the IoT Based Patient Health Monitoring System functions correctly under different conditions. These stages help ensure that the system can accurately monitor health parameters, transmit data, and generate alerts when required.

1. System Testing
System testing is carried out to check whether all hardware and software components operate together without errors. This includes verifying sensor operation, data processing, communication, and alert generation.

1.1 Hardware Testing
Hardware testing is performed to ensure that each physical component of the system works properly.
Microcontroller Testing:
The microcontroller is tested to verify that it receives input from sensors correctly and processes the data without delay. It is also checked for proper communication with other modules. Sensor Testing:

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Each sensor, such as the temperature sensor, heart rate sensor, and SpO_2 sensor, is tested individually. The readings obtained are compared with standard values to confirm accuracy.
Communication Module Testing:
The Wi-Fi or GSM module is tested to ensure that it can send data to the cloud platform without interruption. The stability of the connection is also verified.
Display Unit Testing:
If a display is used, it is checked to confirm that health parameters and system messages are shown clearly.

2. Health Parameter Verification Testing
Experiments are conducted to evaluate how accurately the system measures and identifies patient health conditions.
Initial Measurement
The system first records the patient's health values such as temperature, heart rate, and oxygen level. These values are then compared with normal reference ranges.
Example normal readings:
Temperature = 36.8°C
Heart Rate = 72 bpm
SpO_2 = 98%
These values indicate a stable condition.
Detection of Abnormal Condition
When the readings go beyond normal limits, the system identifies them as abnormal and triggers an alert. Example abnormal readings:
Temperature = 39.5°C
Heart Rate = 120 bpm
SpO_2 = 85%
In such cases, the system generates a warning message for immediate attention.

3. Validation of the System
Validation ensures that the system performs reliably in real-time scenarios.
3.1 Functional Validation
This step verifies whether the system performs its intended operations correctly.
The following functions are checked:
* Collection of health data from sensors * Processing of data by the microcontroller
* Transmission of data to the cloud platform
* Generation of alerts during abnormal conditions
3.2 Performance Validation
Performance validation evaluates how efficiently the system works during operation.
Important factors analyzed include:
* Time taken to read sensor values
* Speed of data transmission
* Accuracy of measured parameters
* Time required to generate alerts
3.3 Reliability Validation
Reliability testing is done by running the system continuously for multiple cycles. This ensures that the system operates without failure and provides consistent results over time.

4. Data Analysis Using Graphical Representation
System performance can be analyzed using graphical methods by comparing normal and abnormal readings. Example Parameters:
X-axis: Test condition (Normal / Abnormal) Y-axis: Sensor values
Example Data:
Condition | Temperature | Heart Rate | SpO_2
Normal | 36.8°C | 72 bpm | 98%
Abnormal | 39.5°C | 120 bpm | 85% The graph clearly shows the variation between healthy and critical conditions.

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5. Interpretation of Results

From the experimental observations, it is clear that the system can effectively monitor patient health. When the measured values are within normal limits, the system continues regular monitoring. If any parameter crosses the safe range, alerts are generated immediately.

As a result:

Continuous monitoring is achieved

Abnormal conditions are detected early

Response time is improved

Patient safety is increased

6. Real-Time Impact of the System

The implementation of this monitoring system provides several advantages in real-world applications.

Continuous tracking of patient health

Reduction in manual monitoring effort

Remote access to health data

Quick alert generation during emergencies

Improved healthcare support

IX. FUTURE SCOPE

The system can be further enhanced by integrating advanced technologies:

1. AI-Based Health Prediction: Artificial intelligence algorithms can analyze historical vital sign data to predict potential cardiac arrests or severe respiratory failures hours before they occur.
2. Smart Hospital Network: Multiple patient monitoring nodes can be connected to a centralized server, allowing a single doctor to monitor an entire hospital ward efficiently from one dashboard.
3. Advanced Sensor Integration: Integrating ECG (Electrocardiogram) sensors and blood pressure monitors will provide a more comprehensive overview of the patient's cardiovascular health.

X. CONCLUSION

The IoT Based Patient Health Monitoring System with Automated Oxygen Supply provides an efficient solution for improving the safety and reliability of critical patient care. Maintaining a patient's vital signs within safe limits is a significant challenge, especially in understaffed environments. In this project, an automated system was developed using biomedical sensors, IoT technology, a microcontroller, and a relay- controlled oxygen pump.

The system successfully monitors important parameters such as SpO2, heart rate, and body temperature. If the patient's oxygen levels drop to dangerous limits, the system automatically dispenses life-saving oxygen via the pump while instantly notifying caregivers through the cloud platform. The automated design reduces manual intervention, improves operational efficiency, and ensures rapid response times.

It can be widely implemented in hospital ICUs, home-care setups, and remote clinics to ensure a safe and reliable healthcare ecosystem.

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