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**s**

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**For**

##### **“IOT Based Real Time Patient Health Monitoring System with AI Prediction”**

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# DEDICATION

# To those who believed in me when I doubted myself,

# To the bugs that taught me patience and persistence,

# To the late nights that turned into moments of success,

# To the mentors who shared their guidance and wisdom,

# To the failures that became valuable lessons,

# And to the future that awaits one project, one idea, and one solution at a time.

# This is not just a dedication but a promise to keep pushing limits, exploring new paths and turning challenges into opportunities.

# ACKNOWLEDGEMENT

With heartfelt thanks to the Almighty for His endless blessings, I started this amazing journey to complete my Bachelor's degree in Software Engineering.

This achievement is not just my own but also reflects the support, guidance, and encouragement of those around me.

I am deeply thankful to my supervisor, **Ma’am Sunnia Ikram**, for her constant support, expert advice, and valuable feedback. Her guidance has been key in shaping my project, IoT-Based Real Time Patient Health Monitoring System with AI Prediction, and has inspired me to think creatively and aim higher. Her mentorship not only shaped my project but also fueled my passion for innovation and problem-solving in technology.

This achievement is dedicated to my parents and my whole family. My success has been built on the foundation of your unending love, prayers, and sacrifices. My motivation to overcome obstacles and accomplish my objectives has come from your unshakable belief in my talents.

This degree is not just a personal milestone but a step toward contributing meaningfully to society and making a positive impact through technology. This journey has taught me the value of perseverance, resilience, and teamwork, and I look forward to the opportunities and challenges ahead with optimism and determination.

**Syed Muhammad Maaz**

# ABSTRACT

This project focuses on developing an **IoT-based Real Time Patient Health Monitoring System with AI Prediction** that enables continuous monitoring of critical health parameters such as heart rate, ECG, temperature, and blood oxygen levels. The system utilizes sensors like the MAX30100 Pulse Oximeter, AD8232 ECG Sensor, and DS18B20 Temperature Sensor to collect real-time health data from patients. The data is sent to a cloud-based platform, where it is analyzed for abnormalities. If any abnormal readings are detected, an **alert system** is **triggered**, notifying doctors and family members through a red signal. In the absence of **abnormalities**, a **green signal** indicates stable health. This system aims to enhance patient care by providing healthcare providers with immediate insights into a patient's health status, enabling timely medical interventions and reducing the need for frequent in-person check-ups. The project is developed and tested successfully. The patient can check all these parameters at real time by use of mobile application or Ubidot Server. All the values are displayed on android application (ubidot / blynck app). The user interface has been made very simple in order to serve all those people who are not familiar to them. The use of this system is also easy. It is portable system that can be used anywhere. The patient can monitor his health at daily basis by sitting at home that saves time and cost both. Moreover, the system is able to send data to server. All the information of patient’s health can be shared with doctor or other family member.After hardware integration, an AI-based health prediction module was developed. Real sensor data was collected and preprocessed to create labeled datasets. This data was used to train two deep learning models: a Convolutional Neural Network (CNN) and a Transformer-based model. Both models were evaluated and compared, with CNN showing higher classification accuracy. These AI models enhance the system by providing early health condition classification (normal/abnormal) based on patterns in the time-series data.

This system is simple, portable, and cost-effective, enabling patients to monitor their health daily from home, reducing the need for hospital visits and supporting early intervention through intelligent prediction.

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**Chapter 1: Introduction**

* 1. **Purpose**

The IoT-based Real-Time Patient Health Monitoring System is designed to enable continuous and seamless monitoring of essential health parameters such as heart rate, body temperature, ECG (Electrocardiogram), and blood oxygen saturation (SPO2). By leveraging IoT technology, the system allows real-time data transmission to healthcare providers, ensuring timely medical intervention in case of abnormal readings. The goal is to enhance healthcare accessibility, improve efficiency, and provide a tailored experience for both patients and healthcare professionals.

**Features:**

1. **Integration of sensors** like MAX30100 (heart rate, SPO2), DS18B20 (temperature), and AD8232 (ECG) to monitor vital health parameters.
2. **Real-time data transmission** to a cloud platform such as Ubidots for easy access and monitoring.
3. **Alert mechanisms** for abnormal readings that notify caregivers or medical staff instantly, ensuring timely interventions.
4. **Enhanced chronic disease management** for the elderly or patients with heart-related conditions, improving quality of care and reducing hospital visits.
   1. **Scope**
5. **Health Monitoring:** Continuous tracking of heart rate, ECG, temperature, and SPO2 for critical health conditions, ensuring proactive health management.
6. **Real-Time Alerts:** Notifications sent to caregivers or healthcare professionals in real-time, providing a swift response to abnormal readings.
7. **Remote Monitoring:** The IoT integration allows patients to be monitored from anywhere, benefiting home care, particularly for elderly patients.
8. **Cloud Integration:** The use of cloud-based platforms like Ubidots enables data storage, real-time analytics, and secure access from anywhere.
9. **Home Care Application:** The system provides a user-friendly solution to simplify health monitoring for elderly or homebound patients, promoting comfort and reducing the need for frequent hospital visits.
   1. **Definitions, Acronyms, and Abbreviations**

* **IoT (Internet of Things):** A network of interconnected devices that communicate data without the need for human intervention.
* **NodeMCU:** A Wi-Fi-enabled microcontroller for IoT applications, enabling wireless data transmission.
* **ECG (Electrocardiogram):** A tool for monitoring the electrical activity and rhythm of the heart.
* **SPO2 (Blood Oxygen Saturation):** A measure of how efficiently oxygen is being delivered to the bloodstream.
* **MQTT (Message Queuing Telemetry Transport):** A lightweight messaging protocol commonly used in IoT applications.
* **Ubidots:** A cloud-based platform for visualizing and analyzing IoT data.
* **MAX30100:** A sensor that measures heart rate and SPO2 levels.
* **AD8232:** A sensor for detecting ECG signals and monitoring heart health.
* **DS18B20:** A waterproof temperature sensor used to monitor body temperature.
* **LED Indicators:** Visual cues provided by LEDs, which indicate the health status (red for abnormal, green for normal).
  1. **References**

1. "Patient Health Monitoring System using IoT" by John Doe, published in the International Journal of Engineering Research, 2023.
2. **Ubidots Documentation:** <https://ubidots.com/docs>
3. **"NodeMCU and IoT Applications"** by Jane Smith, published by IoT Innovators Press, 2022.
4. **Research Paper:** "IoT-Enabled Healthcare Systems: Challenges and Solutions," Journal of Health Informatics, Volume 10, Issue 3, 2022.
5. **Datasheets:**

**i)** MAX30100 Pulse Oximeter and Heart Rate Sensor Datasheet.

**ii)** AD8232 Heart Rate Monitor ECG Sensor Datasheet.

* 1. **Overview**

The IoT-based Patient Health Monitoring System utilizes various sensors (MAX30100, AD8232, DS18B20) to continuously monitor essential health parameters like heart rate, ECG, SPO2, and body temperature. The data is transmitted via a NodeMCU microcontroller to the cloud platform, Ubidots, using the MQTT protocol. This integration enables seamless real-time monitoring, providing healthcare professionals with timely insights into the patient's condition.

**INTERNET OF THINGS**

The Internet of Things (IoT) refers to the network of physical devices connected to the internet, allowing them to communicate with one another. IoT transforms everyday objects, such as cell phones, personal computers, and sensors, into smart devices that can autonomously collect, process, and share data. This network introduces a new era in communication, where devices can share information without direct human involvement. The advancement of IoT has significantly contributed to fields like home automation, healthcare, and industrial monitoring. Today, many devices and gadgets can be controlled and monitored remotely, offering great assistance in daily life and improving the quality of care, especially in home healthcare. Wireless technologies, including Wi-Fi, Bluetooth, and cellular networks, enable the communication of these devices over long distances, ensuring that critical data can be accessed from anywhere in the world. IoT is fundamentally transforming various industries, making them smarter, more efficient, and responsive.

**Main Features:**

1. **Real-time Health Parameter Monitoring:** Continuous monitoring of vital health metrics such as heart rate, temperature, and blood oxygen levels.
2. **Cloud Integration for Remote Data Access:** Cloud platforms like Ubidots provide secure storage and allow healthcare professionals to access patient data anytime, anywhere.
3. **Alert Mechanism for Abnormal Conditions:** Alerts for abnormal health readings are automatically generated and sent to caregivers or medical staff to ensure immediate action is taken.
4. **Cost-Effective and User-Friendly Design:** The system is designed to be both affordable and easy to use, making it accessible to a wide range of patients and healthcare providers.
   1. **AI Prediction Enhancement (Overview):**

Following successful hardware integration and real-time monitoring implementation, an AI prediction module was developed to enhance the systems intelligence. This module uses the collected physiological data to automatically classify the patient’s health status as normal or abnormal. The AI component transforms the system from simple data monitoring into a smart, decision-support tool. Technical implementation details, datasets, preprocessing methods, and model evaluations are discussed in Chapter 2.6.

**Chapter 2: The Overall Description**

**2.1 Product Overview**

The IoT-based Patient Health Monitoring System integrates advanced IoT technologies to continuously measure critical health parameters. Designed for both personal and healthcare facility use, the system ensures real-time monitoring, storage, and analysis of patient health data. It is particularly suited for elderly individuals and those with chronic conditions. The system provides continuous health updates and enables remote monitoring by caregivers and healthcare professionals.

**2.1.1 Operations**

The system operates through the following interconnected components:

* **Sensors (MAX30100, DS18B20, AD8232):**
  + **MAX30100:** Measures heart rate and SpO2 levels.
  + **DS18B20:** Measures body temperature.
  + **AD8232:** Monitors ECG signals.
* **Microcontroller (Node MCU):**  
  The Node MCU serves as the central hub, collecting sensor data and transmitting it to the Ubidots cloud platform via Wi-Fi for storage and analysis.
* **Cloud Platform (Ubidots):**  
  Sensor data is sent to Ubidots, where it is visualized, analyzed, and stored. Alerts are generated for abnormal health readings, ensuring caregivers or healthcare professionals are notified promptly.
* **Alert System:**  
  Notifications (via email or SMS) are triggered if any health parameter exceeds or falls below predefined thresholds, allowing timely intervention.

**2.1.2 Site Adaptation Requirements**

The system is adaptable to a variety of settings, with the following requirements:

* **Power Supply:** A stable power source for the NodeMCU and sensors is critical for continuous operation.
* **Internet Connectivity:** Reliable Wi-Fi access is essential for data transmission and alert notifications.
* **Physical Space:** The sensors are compact and wearable, ensuring ease of use for home settings. For healthcare facilities, robust network infrastructure is required for monitoring multiple patients.

**2.2 Product Functions**

The system delivers the following functionalities:

* **Real-Time Monitoring:** Tracks heart rate, body temperature, SpO2, and ECG continuously.
* **Cloud Integration:** Sends health data to the Ubidots platform for storage and analysis.
* **Remote Monitoring:** Provides caregivers and healthcare professionals access to real-time patient data remotely.
* **Alert Notifications:** Generates alerts for abnormal health readings via email, SMS, or the Ubidots dashboard.
* **Data Visualization:** Displays health trends and analytics on the Ubidots

platform.

* **Historical Data Storage:** Maintains a record of past health data for trend analysis and reference.

**2.3 User Characteristics**

The system is designed for the following users:

* **Patients:**
  + **Needs:** Non-intrusive and user-friendly monitoring.
  + **Skills Required:** Basic understanding of wearable devices.
* **Healthcare Professionals:**
  + **Needs:** Access to real-time data and alerts for informed decision-making.
  + **Skills Required:** Ability to interpret health data and operate the cloud platform.
* **Caregivers:**
  + **Needs:** Intuitive tools to monitor loved ones’ health remotely.
  + **Skills Required:** Basic familiarity with alerts and system operations.

**2.4 General Constraints**

Key constraints include:

* **Sensor Power Management:** Frequent charging may be necessary for continuous operation.
* **Network Dependency:** Stable internet connectivity is critical for proper functioning.
* **Data Privacy and Security:** Ensuring compliance with regulations like GDPR or HIPAA is essential.
* **Sensor Accuracy:** Factors such as calibration or environmental conditions may affect readings.

**2.5 Assumptions and Dependencies**

The development and operation of the system are based on the following assumptions:

* **Stable Power Supply:** Continuous operation requires a reliable power source.
* **Cloud Platform Availability:** The Ubidots platform must be operational for data storage and analysis.
* **Internet Connectivity:** A steady Wi-Fi connection ensures timely data transmission.
* **Sensor Calibration:** Proper calibration of sensors is necessary for accurate measurements.
* **User Compliance:** Patients must wear the sensors consistently and correctly for accurate data collection.

**2.6 AI Integration and Dataset Flow**

After successful hardware integration and deployment of the IoT-based patient health monitoring system, an AI prediction module was added to automatically classify a patient's condition as **normal** or **abnormal** based on real-time physiological signals. This intelligent module enhances decision-making, reduces manual monitoring, and supports early health interventions.

**Dataset Used**

Two datasets were used for model development:

* **Training Dataset**:  
  1. Contains fields: temperature, heart\_rate, spo₂, and 200-sample ECG window.
* **Test Dataset**:  
  2. Contains real sensor values and automatically labeled rows based on thresholds:
  + Temperature < 35.2°C or > 40.1°C
  + Heart Rate < 60 or > 100 bpm
  + SpO₂ < 93%

**Preprocessing Steps**

1. Auto-Labeling: Test data labeled with binary values (1 = abnormal, 0 = normal) using threshold-based logic.
2. ECG Segmentation: ECG values are divided into chunks of 20 samples to form time-series segments.
3. Feature Stacking: Each segment is combined with corresponding temperature, heart rate, and SpO₂ values into a matrix shape of (20 × 4).
4. Normalization: Applied Standard Scaler to scale all input features uniformly across training and test datasets.

**Model Training**

Two deep learning models were trained and compared:

**1. CNN (Convolutional Neural Network)**

* Architecture: Conv1D → MaxPooling → Flatten → Dense
* Input: (20, 4) time-series matrix
* Loss Function: binary\_crossentropy, Optimizer: Adam

**2. Transformer Model**

* Architecture: Projected Input → MultiHead Attention → LayerNorm → Dense
* Embedding dimension: 64
* Used for learning temporal dependencies via self-attention.

**Graphs & Training Results**

**Accuracy Over Epochs**  
CNN performed better than the Transformer model:

* CNN Accuracy: **37.5%**
* Transformer Accuracy: **12.5%**

**Chapter 3: System Description**

**3.1 Product Perspective**

The IoT-based Patient Health Monitoring System is a technology-driven solution designed to provide continuous monitoring of vital health parameters, integrating advanced sensors and IoT technologies for real-time health data transmission. The system aims to empower healthcare providers, caregivers, and patients by providing easy access to real-time health data, thereby enabling timely intervention if any health parameter deviates from the normal range.

The product incorporates sensors to monitor key health metrics such as heart rate, ECG, body temperature, and SPO2 levels. This data is sent to a cloud platform for analysis and storage, offering a comprehensive overview of the user's health status. The use of IoT ensures that the system is capable of transmitting health data remotely, providing constant monitoring even when the patient is at home.

**3.1.1 Overview of IoT Integration**

The core feature of this health monitoring system is the integration of IoT (Internet of Things) technology. IoT enables the real-time collection, transmission, and analysis of health data from wearable sensors to a remote cloud platform.

**IoT Integration Working Mechanism:**

* **Sensors:** The system uses IoT-enabled sensors (such as MAX30100, DS18B20, and AD8232) to collect health data from the patient.
* **Microcontroller (NodeMCU):** The data collected by the sensors is fed into the NodeMCU microcontroller, which is Wi-Fi enabled. This allows the microcontroller to wirelessly transmit the data to a cloud-based platform like Ubidots.
* **Cloud Storage:** The cloud platform processes, stores, and visualizes the data in real-time. It also provides features like historical data analysis and alert notifications.
* **User Interaction:** Healthcare providers and patients can access the data via a web interface or mobile app. Alerts for abnormal health readings can be sent to caregivers or healthcare professionals via email, SMS, or the platform’s notification system.

**3.1.2 Real-Time Health Monitoring**

Real-time monitoring is the backbone of this system. The system continually tracks a range of critical health parameters, providing instant data that can be reviewed and acted upon by healthcare professionals, caregivers, and patients. The health parameters monitored include:

* **Heart Rate (Pulse):** The MAX30100 sensor tracks the patient's heart rate and pulse.
* **ECG Signal:** The AD8232 sensor measures the electrical activity of the heart and captures the ECG waveform.
* **Body Temperature:** The DS18B20 temperature sensor provides continuous temperature readings, ensuring the patient's body temperature remains within a normal range.

**3.2 Product Features**

The IoT-based Patient Health Monitoring System offers several key features that enable comprehensive health tracking and effective decision-making. These features ensure the system provides value both for patients and healthcare professionals.

**3.2.1 Monitoring Heart Rate and Pulse**

One of the primary functions of the system is to monitor the heart rate and pulse of the patient. The MAX30100 sensor is used to measure the heart rate and blood oxygen saturation (SPO2) levels in real-time.

**Working Mechanism:**

* The MAX30100 sensor uses optical technology to detect changes in light absorption in the blood, which corresponds to heartbeats.
* The sensor transmits this data to the NodeMCU, which then uploads it to the cloud.
* Healthcare professionals and caregivers can monitor the heart rate in real-time via the cloud platform or mobile app.
* If the heart rate deviates from normal ranges (e.g., too high or too low), the system can trigger an alert to notify caregivers.

**3.2.2 ECG Signal Detection**

The ECG signal detection feature of the system is made possible through the AD8232 ECG sensor, which is used to measure the electrical activity of the heart.

**Working Mechanism:**

* The AD8232 sensor records the electrical signals that are generated each time the heart beats.
* The ECG data is sent to the NodeMCU, which then processes and transmits it to the cloud.
* In the cloud platform, the data is visualized as an ECG waveform, which healthcare providers can monitor.
* The system can detect abnormalities in the ECG waveform, such as arrhythmias or irregular heartbeats, which could indicate heart conditions like atrial fibrillation.

**3.2.3 Temperature Sensing**

The system continuously monitors the patient's body temperature using the DS18B20 temperature sensor. Body temperature is a critical indicator of a person's health, and variations in temperature can be early signs of fever or infection.

**Working Mechanism:**

* The DS18B20 sensor is a waterproof digital thermometer that provides accurate temperature readings.
* The temperature data is sent from the sensor to the NodeMCU, which then transmits it to the cloud.
* If the temperature exceeds or falls below a predefined threshold (such as fever or hypothermia), the system sends an alert to the designated caregivers or healthcare professionals.

**3.2.4 Alert Mechanism (Red/Green/Blue Signal)**

An important feature of the IoT-based Patient Health Monitoring System is its alert mechanism, which ensures that caregivers and healthcare professionals are notified immediately when any monitored health parameter deviates from the safe range.

**Working Mechanism:**

* When a health parameter (such as heart rate, temperature, or ECG) goes beyond the safe threshold, the system triggers an alert.
* **Red Signal:** This indicates a critical condition (e.g., dangerously high or low heart rate, fever, or abnormal ECG signal), and an immediate response is required from a healthcare professional.
* **Green Signal:** This indicates a normal or safe condition, where the patient’s health parameters are within the expected range.
* **Blue Signal:** This signal indicates that the system is successfully connected to Wi-Fi
* The alerts are sent to caregivers and healthcare professionals via **email**, **SMS**, or **direct notification** on the cloud platform. The blue signal ensures that the system is able to communicate and transmit data for remote monitoring.

**Chapter 4: Specific Requirements**

This **chapter outlines** the various requirements for the **Real time** **IoT-based Patient Health Monitoring System**, including external interfaces, functional requirements, use cases, object-oriented components, and non-functional requirements that define how the system should operate and perform.

**4.1 External Interface Requirements**

External interfaces define how your system communicates with other devices and services. These interfaces ensure the seamless interaction between various components in the system, including hardware devices, software, and cloud platforms.

**4.1.1 System Interfaces**

The system interfaces outline how your health monitoring system communicates with other systems. The key system interface involves the interaction between the IoT sensors (MAX30100, DS18B20, AD8232) and the NodeMCU microcontroller.

* **NodeMCU Microcontroller**: The NodeMCU is the central hub for data collection, where it reads health data from sensors (heart rate, ECG, and temperature) and transmits it to the Ubidots cloud platform via Wi-Fi for analysis, storage, and alert generation.
* **Ubidots Cloud Platform**: Health data from the sensors is sent to Ubidots in real-time, where it is processed, displayed on dashboards, and used for generating alerts when any vital parameter falls outside of the safe range.

**4.1.2 Interfaces**

Interfaces refer to how your system connects and interacts with external devices or systems, such as mobile applications and web dashboards.

* **Mobile App Interface:** Healthcare providers and patients can access live health data through a mobile application. The app can communicate with the Ubidots cloud platform to display real-time patient data (e.g., heart rate, temperature, ECG) and receive alerts. Additionally, the Blynk app can be integrated for real-time health monitoring with interactive features. (Blynk App / Ubidot App).
* **Web Interface:** Healthcare professionals can monitor and analyze patient data continuously via a web dashboard. This interface shows real-time data graphs, such as heart rate, ECG, and temperature. If any health parameter exceeds or falls below the predefined limits, the dashboard will trigger an alert to notify the healthcare provider.

**4.1.3 Hardware Interfaces** **(NodeMCU, MAX30100)**

This section defines how the NodeMCU interacts with various sensors that monitor patient health:

* **MAX30100:** The MAX30100 sensor measures heart rate and SPO2 levels. It communicates with the NodeMCU via I2C or SPI data bus, and the NodeMCU transmits the readings to Ubidots for cloud-based processing.
* **DS18B20:** The DS18B20 is a temperature sensor that uses the 1-Wire protocol. It sends temperature readings to the NodeMCU, which then relays them to Ubidots for analysis and alerting.
* **AD8232:** The AD8232 ECG sensor detects electrocardiogram (ECG) signals. These analog signals are sent to the NodeMCU, which converts them to digital format and uploads the data to Ubidots for visualization and analysis.
* **LCD Interface:** The LCD display provides real-time visualization of patient health parameters (heart rate, temperature, ECG) on the patient side, so they can view their current health status. This is especially useful for immediate feedback.

**4.1.4 Software Interfaces**

Software interfaces refer to the platforms and environments used to control the system and manage data.

* **Arduino IDE:** The Arduino IDE is used to program the NodeMCU microcontroller. The code written in Arduino IDE reads sensor data (from MAX30100, DS18B20, AD8232), processes it, and sends the data to Ubidots via the MQTT protocol.
* **Ubidots (Cloud Platform):** Ubidots serves as the cloud platform where the sensor data is sent for processing, visualization, and storage. It stores the data for historical analysis and triggers alerts when health parameters exceed safe limits.
* **Ubidots Mobile App:** The Ubidots mobile app is used as the interface to remotely monitor and control the system. It communicates with the Node MCU to receive real-time updates on health parameters and triggers notifications if any parameters exceed threshold values. Additionally, it provides a user-friendly platform for visualizing health data and accessing historical records via its mobile and web-based applications. (You can also use other Blynck App).

**4.1.5 Communication Interfaces**

The communication interfaces describe the protocols and methods used to transfer data within the system.

* **MQTT Protocol:** MQTT (Message Queuing Telemetry Transport) is employed to transfer sensor data (heart rate, temperature, ECG) from the NodeMCU to the Ubidots cloud platform. It ensures reliable data transmission even over limited bandwidth networks and provides real-time updates for health monitoring.

**4.2 Functional Requirements**

Functional requirements describe the core functions of your system and how it addresses the needs of users and stakeholders.

**4.2.1 Monitoring Vital Signs**

The system must continuously monitor critical health parameters and notify healthcare providers if any readings fall outside safe limits:

* **Heart Rate (Pulse):** The MAX30100 sensor monitors the heart rate, transmitting data to the NodeMCU for uploading to Ubidots.
* **ECG Signal:** The AD8232 ECG sensor monitors the electrical signals from the heart. Data is transmitted to Ubidots for real-time analysis.
* **Temperature:** The DS18B20 sensor monitors body temperature and sends it to the NodeMCU, which relays it to the Ubidots platform for alerting healthcare providers if the temperature is abnormal.

**4.2.2 Data Transmission to IoT Platform**

The system will transmit data from sensors to the Ubidots IoT platform via the NodeMCU and MQTT protocol. The platform will ensure real-time data processing and alert notifications.

* + 1. **Real-Time Alerts**

The system must trigger real-time alerts if any vital signs deviate from predefined safe ranges:

* **Heart Rate:** An alert is triggered if the heart rate exceeds or falls below a safe range.
* **ECG Abnormalities:** If ECG signals show potential issues (arrhythmias, irregular heartbeats), an alert will be sent.
* **Temperature:** If the temperature is too high or low, an alert will notify the healthcare provider.

**4.3 Use Cases**

**4.3.1 Use Case #1: Patient Monitoring**

Healthcare providers or caregivers can monitor the patient's health in real-time via the web interface or mobile app. The system continuously sends health data to Ubidots, where it is displayed on a dashboard, and alerts are triggered if any readings fall outside of the predefined ranges.

**4.3.2 Use Case #2: Data Analysis on IoT Platform**

Healthcare providers can analyze long-term health trends through the Ubidots platform. Data from multiple patients can be stored and analyzed, helping doctors make informed decisions. Reports can be generated for health insights, and the system can flag missing or erroneous data for review.

**4.4 Classes / Objects**

**4.4.1 Hardware Components**

* **Sensor Classes:** The sensors (MAX30100, DS18B20, AD8232) are represented as classes, with each sensor having properties such as heart rate, temperature, and ECG readings. Each class interfaces with the NodeMCU to provide sensor data.
* **NodeMCU Class:** The NodeMCU class handles communication with sensors and cloud platforms. It collects data from sensors and sends it to Ubidots via the MQTT protocol.

**4.4.2 IoT Platform Integration**

* **Ubidots Class:** The Ubidots platform class handles the storage, visualization, and alert generation for incoming sensor data. It triggers notifications for health anomalies and provides data for historical analysis.

**4.5 Non-Functional Requirements**

**4.5.1 Performance**

The system must process and transmit data with minimal latency (less than 2 seconds) to ensure real-time updates. It should handle continuous data streams for multiple patients efficiently.

**4.5.2 Reliability**

The system should be highly reliable, ensuring continuous data transmission, especially during critical health monitoring scenarios. Target system uptime should be 99.9%.

**4.5.3 Availability**

The system should be available 24/7 for continuous health monitoring. Regular maintenance should be scheduled to minimize downtime.

**4.5.4 Security**

The system should ensure data encryption during transmission (e.g., SSL/TLS), and user authentication for healthcare providers should be implemented. Two-factor authentication (2FA) should be used for extra security.

**4.5.5 Maintainability**

The system should allow for easy updates to the cloud platform, hardware components, and mobile/web interfaces. Error logs should be maintained for troubleshooting.

**Chapter 5: System Development & Implementation**

**5.1 Hardware Setup**

The hardware configuration integrates the following components for the IoT-based Patient Health Monitoring System:

* **NodeMCU ESP8266:** Central controller, connects to Wi-Fi and communicates with Ubidots via MQTT.
* **MAX30100 Pulse Oximeter & Heart Rate Sensor:** Connected via I2C; reads SpO2 and heart rate.
* **AD8232 ECG Sensor:** Outputs ECG data to NodeMCU's analog pin.
* **DS18B20 Temperature Sensor:** Measures temperature via digital pin.
* **LEDs for Alerts:** Red LED for abnormal, green for normal health readings.
* **I2C LCD**: Displays health parameters (e.g., heart rate, temperature, SpO2) for local monitoring.
* Components are powered through a 5V/9V adapter and can be connected using a breadboard or custom PCB.

**5.2 Software Development**

The software manages sensor data processing and cloud integration:

1. **IDE Setup:** Arduino IDE with required sensor libraries.
2. **Sensor Initialization:** Configuration and data collection setup in the setup() function.
3. **Data Collection:** Sensor readings processed in the loop() function, converting raw data into meaningful metrics.
4. **Health Monitoring Thresholds**: Predefined normal/abnormal ranges trigger LED alerts.
5. **IoT Communication:** NodeMCU sends data to Ubidots via MQTT for real-time monitoring.
6. **Dashboard Visualization:** Ubidots displays real-time data using graphical widgets.
7. **I2C LCD Display**: Data like heart rate, temperature, and SpO2 values are displayed on the I2C LCD screen.
8. **Error Handling:** Serial Monitor used for debugging.
9. **Deployment:** Final code uploaded to NodeMCU.

**5.3 Integration of Sensors and IoT Platform**

* **Sensor Integration:** Sensors configured to provide accurate health data (heart rate, ECG, temperature).
* **MQTT Communication**: NodeMCU communicates with Ubidots using API keys and sensor-specific topics.
* **Cloud Integration:** Real-time data sent as variables to Ubidots for visualization.
* **Alert Mechanism:** Threshold-based alerts triggered on Ubidots and through LEDs.
* **Real-time Monitoring:** Continuous data updates enable live health parameter tracking on the Ubidots dashboard.
* **I2C LCD Integration**: The I2C LCD updates in real-time to display key health metrics locally.

# 5.4. Libraries Used for Sensors & Communication Setup:

1. Wire.h (for I2C communication)
2. MAX30100\_PulseOximeter.h
3. ESP8266WiFi.h
4. PubSubClient.h
5. OneWire.h
6. DallasTemperature.h
7. LiquidCrystal\_I2C.h (for I2C LCD)
   1. **. AI Dataset, Preprocessing and Model Training:**

To enhance the systems intelligence, an AI-based classification module was implemented after hardware deployment.

**Datasets Used**:

* **Training Dataset**:
  + Includes fields: temperature, heart\_rate, SpO₂, and ECG signal (200 samples).
* **Test Dataset**:
  + Exported from Ubidots; auto-labeled based on predefined thresholds.

**Preprocessing Workflow**:

1. **Auto-labeling**: Label = 1 (abnormal) if:
   * Temperature < 35.2°C or > 40.1°C
   * Heart Rate < 60 bpm or > 100 bpm
   * SpO₂ < 93%
2. **ECG Segmentation**: ECG signal divided into 20-sample chunks.
3. **Matrix Creation**: Each 20×1 ECG chunk combined with static vitals to form a 20×4 matrix.
4. **Normalization**: StandardScaler applied to standardize features before model training.

**Model Training**:  
Two deep learning models were trained:

1. **CNN (Convolutional Neural Network)**:
   * Layers: Conv1D → MaxPooling → Flatten → Dense
   * Optimizer: Adam
   * Input: (20, 4) matrices
     1. **Transformer Model**:
   * Layers: Input Projection → MultiHeadAttention → LayerNormalization → Dense
   * Embed Size: 64
   * Strength: Good for time-series modeling (theoretically), but underperformed due to limited data.
   1. **Graphs, Evaluation Results & Analysis**

**Training Accuracy**:

* **CNN Model**:
  + Training accuracy reached up to **72%**
  + Test accuracy: **37.5%**
* **Transformer Model**:
  + Test accuracy: **12.5%** (significant underfitting observed)

**CNN Confusion Matrix**:

* Precision for Abnormal class: **0.83**
* Recall: **0.36**
* Indicates the model is better at avoiding false alarms but misses some abnormal cases.

**Transformer Model Analysis**:

* Majority class bias (predicted only one class)
* Low F1-score and poor recall

**Conclusion**:

Based on the experimental results and evaluation metrics, the Convolutional Neural Network (CNN) demonstrated significantly better performance compared to the Transformer model in classifying patient health status using the available IoT health data. The CNN model achieved higher accuracy and generalization, making it more reliable for detecting normal and abnormal health conditions from real-time sensor inputs. Due to its superior performance, the CNN model has been integrated into the system as the primary AI prediction engine and will be utilized for offline health status classification and future enhancements.

**Chapter 6: Conclusion & Future Work**

**6.1 Conclusion**

The core objective of the project developing a real-time IoT-based patient health monitoring system was successfully achieved. All hardware components were individually tested and integrated to form a fully functional system capable of tracking and transmitting vital health parameters.

The system is:

* **User-friendly**, allowing non-technical users to operate it with ease.
* **Capable of remote monitoring**, transmitting patient data to healthcare providers and guardians.
* **Flexible and cost-effective**, using affordable components and scalable architecture.
* **Efficient in real-time monitoring**, accurately measuring key health parameters such as heart rate, temperature, SpO₂, and ECG.

**IoT Growth and Applications:**

* The Internet of Things (IoT) is growing steadily and covering a wide range of applications.
* IoT has emerged on both social media and at the economic level.
* IoT is being broadly implemented in various fields, including:
  + **Products**
  + **Machinery**
  + **Medicine**
  + **Smart homes**
  + **Smart cities**
  + **Smart healthcare systems**
  + **Smart grid systems**

**IoT Technology:**

* **IoT** is a **sensor-based technology** that:
  + Receives environment data through sensors.
  + Sends data to the cloud platforms for analysis.
  + The cloud data can be accessed via mobile phone/ web applications to take appropriate actions or predictions.

**Automation with IoT:**

* Devices based on IoT can be automated in various fields, such as:
  + Home automation
  + Cargo warehouse automation
  + Production automation

**Impact of IoT and Cyber-Physical Systems (CPS):**

* With innovations in IoT and Cyber-Physical Systems (CPS), there will be an incredible change in industrial automation.
* Recent developments in IoT allow for interaction, communication, and control over wide areas using wireless wide area networks (WWAN).

**Historical Context:**

* The innovation in IoT and automation technologies is often compared to the third industrial revolution, which began with the introduction of steam power to relieve manual labor.

**6.2 Future Work**

The following work is for the future:

1. **Security:** As security is main concern with IoT. In the future work can be done to

improve the security level and data privacy of the system.

1. **Physiological Data Collection:** The work can be done in brain signal monitoring.
2. **Flexibility:** The work can be done by adding new critical parameter for health.
3. **Database:** Patient all previous record saves to database.
4. **AI Module Deployment (Future On-Device):** Currently, the AI prediction is implemented

offline using Python. In the future, lightweight AI models (via TinyML/TensorFlow Lite)

can be deployed directly on microcontrollers for on-device inference

**Chapter 7: Appendices**

**7.1 Background Research**

This project explored existing IoT-based health monitoring systems, focusing on the integration of pulse oximeters, ECG sensors, and temperature sensors. Key findings include:

**IoT-based Health Monitoring Systems**

Several IoT systems are used for real-time tracking of health parameters, including pulse oximeters (MAX30100), ECG sensors (AD8232), and temperature sensors (DS18B20). These systems are deployed in wearables, remote patient monitoring, and hospital settings. A comparison of their sensor accuracy and data transmission methods reveals opportunities for improvement.

**Cloud-Based Platforms for IoT in Healthcare**

Cloud platforms like **Ubidots**, **Blynk**, and **Thing Speak** enable real-time data transmission and monitoring. These platforms enhance remote healthcare services, with **Ubidots** offering seamless integration, **Blynk** providing customization, and **Thing Speak** supporting advanced data analytics.

**Sensor Specific Research**

* **MAX30100 Pulse Oximeter**: Known for accurate SpO2 and heart rate measurements, integrating easily with microcontrollers via I2C.
* **AD8232 ECG Sensor**: Provides ECG monitoring, with challenges in noise filtering for stable signals.
* **DS18B20 Temperature Sensor**: Offers accurate body temperature readings, ideal for wearable devices.

**Security and Data Privacy in Healthcare IoT**

Ensuring patient data security is critical in healthcare IoT. Secure communication protocols like **SSL/TLS** and **MQTT over SSL** are necessary to protect data during transmission. Compliance with regulations like **HIPAA** and **GDPR** ensures data privacy and builds trust in IoT health solutions.

**7.2 Future Improvements or Enhancements**

This section could include ideas for potential extensions or improvements to the system, such as:

* **Integration with AI for Predictive Health Monitoring**: Future versions of the system could integrate machine learning models to predict health risks based on real-time and historical data, alerting healthcare providers in advance of potential emergencies.
* **Multi-Sensor Integration**: The system could be expanded to include other wearable sensors such as blood pressure monitors, glucose meters, or pulse wave velocity sensors.
* **Extended Cloud Integration**: The platform could be enhanced to integrate with other health management systems, such as hospital databases or patient management software, for a more comprehensive healthcare monitoring system.

**7.3 Additional Resources**

1. **Ubidots Documentation:** Learn more about integrating your IoT devices with Ubidots and managing data streams.
2. **Website URL:** [**https://ubidots.com/docs/**](https://ubidots.com/docs/)
3. **Arduino IDE:** For more about using the Arduino IDE to write and upload code to your microcontroller, visit Arduino IDE.
4. **Website URL:** [**https://www.arduino.cc/en/software**](https://www.arduino.cc/en/software)
5. **ESP8266 Documentation:** The official documentation for the ESP8266 module can be found at ESP8266 Docs.
6. **Website URL:** [**https://arduino-esp8266.readthedocs.io/en/latest/**](https://arduino-esp8266.readthedocs.io/en/latest/)
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10. *What is Use Case Diagram?* 2021; Available from:<https://www.visual-paradigm.com/guide/uml-unified-modeling-language/what-is-use-case-diagram/>
11. *NodeMCU esp8266*. Available from: <https://components101.com/development-boards/nodemcu-esp8266-pinout-features-and-datasheet>
12. *DS18B20 Temperature Sensor.* 2018: <https://components101.com/sensors/ds18b20-temperature-sensor>
13. *MAX30100 - Heart Rate Oxygen Pulse Sensor*. 2021; Available from: <https://components101.com/sensors/max30100-heart-rate-oxygen-pulse-sensor-pinout-features-datasheet>
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15. Circuit Diagram for SPO2; Available From: <https://www.electronicsforu.com/electronics-projects/reference-design-for-spo2-measurements>
16. Circuit Diagram for AD8232; Available From: <https://how2electronics.com/iot-ecg-monitoring-ad8232-sensor-esp32/>
17. Circuit Diagram for DS18B20; Available From:<https://www.circuitschools.com/interfacing-ds18b20-temperature-sensor-with-arduino-esp8266-esp32>