HANOI UNIVERSITY OF SCIENCE AND TECHNOLOGY
SCHOOL OF ELECTRICAL AND ELECTRONIC ENGINEERING

FINAL REPORT
INTERNET OF MEDICAL THINGS

INDOOR ENVIRONMENT QUALITY MONITORING SYSTEM IN EEG LAB

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ABSTRACT

The accuracy of EEG (electroencephalography) readings can be impacted by internal environmental elements such light, temperature, humidity, and air quality, which have been shown to have a substantial impact on brainwave activity in recent research. It has been demonstrated that these external factors, which frequently change in real time, add unwelcome noise and fluctuation to EEG readings, potentially resulting in incorrect interpretations of brain activity. In several domains, such as clinical diagnostics, brain-computer interfaces, and cognitive neuroscience, precise EEG readings are essential. The objective of this research is to create a cutting-edge Internet of Things (IoT)-based tool that can continually monitor and adjust environmental parameters in a controlled environment in real-time in order to overcome this difficulty. To maintain a steady and ideal experimental environment for EEG readings, this gadget will be outfitted with sensors to monitor and modify the levels of light, temperature, humidity, and air quality. The gadget will reduce the impact of outside variables on EEG data by preserving a constant environment, enabling more accurate and dependable readings that accurately capture variations in brain activity. It is anticipated that this invention will raise the caliber and precision of EEG tests, increasing their usefulness in clinical and research settings and ultimately advancing our knowledge of brain illnesses and functions.

CHAPTER 1. INTRODUCTION

1.1 Problem Statement

In a recent study published in 2023, the effects of indoor environmental factors on employee productivity were assessed within the same building, with a particular focus on how these factors influence brainwave activity. To evaluate brainwave activity and its correlation with environmental conditions, EEG electrodes were strategically placed on the F3 and F4 regions of the brain, corresponding to the left and right frontal lobes. The frontal lobes are key areas involved in cognitive functions such as behavioral inhibition, judgment, and decision-making, which are critical to an individual's ability to perform complex tasks. The study utilized EEG indices, including Rb, RT, RSMT, and RBT, to examine the physiological responses of the brain to different environmental factors, particularly light and noise.

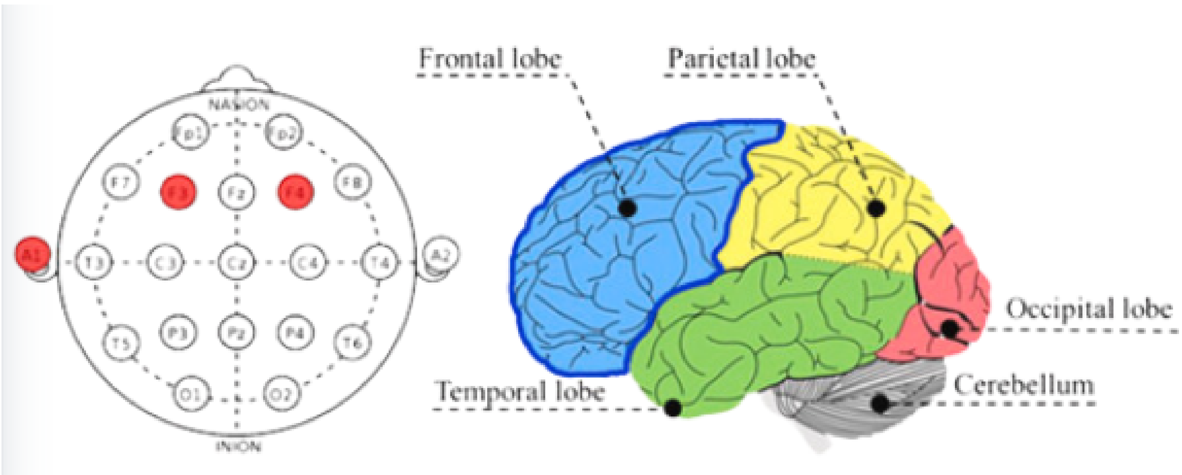

Figure 1.1 EEG electrodes placing

The research employed a two-way ANOVA to analyze the effects of light and noise on the EEG indices. The p-values derived from the analysis were used to determine the statistical significance of these environmental factors, with a threshold of 0.05 to denote a significant influence. The results of the study indicated that both noise and the interaction between noise and light had a significant impact on several of the EEG indices, as the majority of the p-values were found to be less than 0.05. This suggests that fluctuations in noise levels and the combined effects of noise and light can have substantial effects on brainwave activity, thereby influencing cognitive functions and overall productivity.

This study highlights the importance of understanding how indoor environmental factors, such as light, noise, temperature, humidity, and air quality, can affect brainwave activity, particularly in settings where precise and reliable EEG measurements are

Two-way ANOVA according to physiological response by IEQ manipulated variables.

		Illuminance		**Noise**		**Illuminance* Noise**	
		F	p-value	F	p-value	F	p-value
RB	F3	.496	.485	3.272	.077	2.157	.149
	F4	.539	.466	6.275	**.016***	5.864	**.019***
RT	F3	.089	.767	5.628	**.022***	1.982	.166
	F4	.045	.834	8.524	**.005****	6.040	**.018***
RSMT	F3	.036	.849	4.286	**.044***	.580	.450
	F4	.177	.676	6.990	**.011***	4.513	**.039***
RBT	F3	.002	.961	4.602	**.037***	.141	.709
	F4	.209	.649	7.361	**.009****	3.008	.089

Note: * p-value < .05; ** p-value < .01; RB relative beta; RT relative theta; RSMT ratio of SMR to beta; RBT ratio of beta to theta.

Figure 1.2 The effects of indoor environmental factors on employee productivity were assessed within the same building

required. These environmental variables can introduce unwanted variability and noise into EEG signals, leading to potential inaccuracies in the measurement of brain activity. For example, in high-precision experiments or clinical settings where accurate EEG readings are critical, such environmental fluctuations can compromise the integrity of the results.

In light of these findings, the goal of our research is to develop an IoT-based device capable of continuously monitoring and adjusting key environmental factors in real-time. This device would be deployed in experimental environments or laboratories to ensure that the conditions remain optimal for EEG measurements. The system would monitor variables such as light intensity, temperature, humidity, and air quality, and make real-time adjustments to maintain a stable and controlled environment. By doing so, we aim to eliminate the influence of fluctuating environmental factors, ensuring that EEG measurements more accurately reflect true changes in brain activity, without being skewed by external variables.

The development of this IoT device represents a crucial step toward improving the precision and reliability of EEG-based experiments. It will enhance the reproducibility of results in both research and clinical applications by mitigating the impact of environmental noise on EEG data. This approach will help to ensure that the measurements obtained from EEG experiments are not only consistent but also truly indicative of the subject's cognitive and neurological states. Ultimately, this innovation will contribute to advancing our understanding of brain functions and disorders, enabling more accurate diagnoses and effective treatments in the field of neuroscience and beyond.

1.2 Standard Environmental Factors in EEG Laboratory

Maintaining these standard conditions ensures not only the accuracy of EEG data but also the health and safety of the individual being monitored. Proper environmental control is critical to achieving reliable, artifact-free EEG recordings, which are essential for accurate diagnosis and analysis.

Factors	Acceptable Range	Effect
Temperature	20- 25°C	Ensure comfort for participants and stable electrode contact.
Humidity	30 - 60% RH	Prevent excessive sweating (high humidity) or dry skin (low humidity)
Noise	<35dB	Low levels of noise are essential, as even background noise can disrupt EEG readings
Illumination	300-500 Lux	Soft, indirect lighting to avoid glare or excessive brightness that may affect EEG data
CO2 concentration	<1000 ppm	High levels of CO_2 can affect cognitive performance and brainwave patterns
CO concentration	<10 ppm	High levels of CO can impair cognitive function and lead to health risks, which can affect EEG results

Figure 1.3 Standard Environmental Factors in EEG Laboratory

1.2.1 Temperature

Maintaining a stable temperature between 20°C and 25°C is crucial for the physiological comfort of the individual being monitored. If the temperature is too low, the skin becomes dry, which hinders the electrical conductivity of the skin, making it difficult for electrodes to establish a stable connection. On the other hand, if the temperature is too high, sweating occurs, which can alter the skin's conductivity and lead to excessive noise in the EEG signals. Both extremes impact the accuracy of the EEG data.

1.2.2 Humidity

The relative humidity needs to be kept between 30% and 60%. Humidity that is too low dries out the skin, reducing the contact quality between the skin and electrodes. High humidity, on the other hand, encourages sweating, which can cause skin impedance to fluctuate and lead to poor signal quality or signal contamination. This can severely impact the reliability of EEG recordings, which are sensitive to such changes.

1.2.3 Noise

The noise level should be kept below 35 dB. Environmental noise can introduce electrical interference, which results in artifacts that distort the EEG signals. Keeping the noise level low is necessary to ensure clean data collection, avoiding distortions that could lead to inaccurate results or misinterpretation of brain activity.

1.2.4 Lighting

The lighting in the EEG room should be maintained between 300 and 500 Lux. This level of illumination is ideal for reducing eye strain and minimizing artifacts caused by eye movements, which are often reflected in EEG signals. Extreme lighting conditions—either too bright or too dim—can introduce additional variables that make it harder to interpret the brain wave activity accurately.

1.2.5 CO2 concentration

The concentration of CO_2 should be kept below 1000 ppm. Elevated levels of CO_2 can cause cognitive impairment, such as dizziness, headaches, and decreased concentration. These physiological changes can affect brain wave patterns and lead to distorted EEG readings. High CO_2 levels in the room can also present a health risk to the person being monitored, potentially leading to a dangerous environment if not properly ventilated.

1.2.6 CO concentration

The concentration of CO should be kept below 9 ppm. Carbon monoxide is a toxic gas that can impair brain function and lead to alterations in brain activity patterns. High levels of CO can cause confusion, dizziness, and unconsciousness, and can severely affect the reliability of EEG data. Ensuring the room is well-ventilated and free of CO is vital for both the safety of the individual being monitored and the quality of the EEG recording.

1.3 Functional and Nonfunctional Requirements

1.3.1 Functional Requirements

a. Environmental Monitoring

The system must continuously monitor critical environmental factors such as temperature, humidity, CO_2 concentration, CO levels, noise, and light to ensure that all conditions remain within the specified standards for accurate EEG data collection. This includes detecting real-time fluctuations in environmental parameters and triggering alerts if any parameters deviate from acceptable thresholds. These environmental conditions play a crucial role in maintaining the quality of the EEG signals, so constant monitoring is essential to minimize data inaccuracies.

b. Real-time Data Collection

The system should be capable of collecting real-time data from various environmental sensors and providing immediate feedback to the user interface. The collected data should be displayed in an easy-to-understand format, allowing users to monitor environmental conditions continuously. Real-time data collection is critical for ensuring that immediate corrective actions can be taken if any of the environmental factors move outside the acceptable range, thus preventing any potential impact on the EEG results.

c. Data Logging and Storage All environmental data must be logged continuously and stored securely for future reference and historical analysis. This data should be accessible in a user-friendly manner for later analysis, allowing the system to generate reports or trends over time. This logging system should be able to handle large amounts of data and store it for extended periods, ensuring it is available for audit, troubleshooting, and further research. Additionally, the system should provide secure and easy access to the stored data, allowing authorized personnel to review past conditions and correlate environmental factors with EEG results.

d. Integration with EEG System The environmental monitoring system should be seamlessly integrated with the EEG system. This integration ensures that the environmental data is taken into account during the EEG analysis, providing more accurate and reliable results. For example, temperature and humidity levels could influence skin impedance and EEG signal quality, and the system should be able to flag such conditions during the analysis process. By combining these two systems, the overall accuracy and reliability of the EEG recordings are improved, as the environmental factors can be adjusted or controlled based on real-time input from the monitoring system.

1.3.2 Nonfunctional Requirements

a. Data Integrity and Accuracy

The system must ensure that the data collected from environmental sensors is both reliable and accurate. This can be achieved through regular calibration of the sensors and validation against known standards. Any discrepancies or sensor malfunctions should trigger immediate alerts, and corrective actions should be taken to prevent inaccurate readings. Data integrity is essential for both operational efficiency and the accuracy of EEG analysis, as even small deviations in environmental parameters can lead to significant errors in the results.

b. Scalability

The system must be designed to scale easily, allowing for the integration of additional sensors or new devices without affecting overall performance. As the laboratory or monitoring environment grows, the system should be able to handle an increased number of sensors and more complex data analysis without compromising on speed or reliability. This scalability ensures that the system remains flexible, cost-effective, and adaptable to future technological advancements or changes in requirements.

c. Security The environmental and EEG data must be encrypted during both transmission and storage to protect it from unauthorized access or potential loss. The system should employ industry-standard encryption protocols to safeguard sensitive data, ensuring that both the EEG data and the environmental conditions remain confidential and secure. This is crucial, particularly in medical and research environments where data privacy is paramount, and any data breaches could lead to serious consequences. Furthermore, the system should support access control features to ensure that only authorized personnel can access sensitive data.

d. Usability The system should provide an intuitive and user-friendly interface that can be easily operated by laboratory staff without requiring extensive training. The interface should display data in an accessible format and allow users to interact with the system efficiently. The design should prioritize ease of use, minimizing complexity and ensuring that the system's features are straightforward and responsive. This ease of use is essential for ensuring that staff can focus on their primary tasks without being distracted by complicated system operations, leading to better productivity and fewer errors in monitoring.

CHAPTER 2: CONCEPTUAL DESIGN

2.1 Communication Protocol and Method Selection

2.1.1 Bluetooth

Bluetooth is a wireless communication technology designed for short-range data transmission between devices. In this project, Bluetooth serves as the primary communication method between the Arduino microcontroller and the Raspberry Pi. It offers compactness and flexibility, making it highly suitable for the laboratory environment, where organized and clutter-free setups are essential to avoid interference with sensitive signals like EEG.

Criteria	Bluetooth	Wi-Fi	USB cable
Range	Medium (10m), suitable for lab environment	Large	Short
Data Rate	Medium (1 Mbps)	High (100 Mbps)	High
Stability	Good, low interference in short range	Depends on Wi-Fi network quality	Very stable
Cost	Low	Medium	Very low
Power Consumption	Low	Higher	Negligible
Scalability	Medium (optimal for 1-to-1 or few devices)	High (supports many devices over network)	Low (1-to-1, difficult to scale)
Conclusion	Suitable (compact, flexible, stable)	Good (but overkill for small range)	More cumbersome

Table 2.1 Comparison of Bluetooth, Wi-Fi, and USB Cable Communication Methods

Compared to other methods such as Wi-Fi and USB cable, as shown in Table 2.1 Bluetooth stands out due to its balance of performance, cost, and practicality:

1. **Range and Efficiency:** Bluetooth provides an optimal range of approximately 10 meters, which is ideal for small lab setups. It avoids the unnecessary complexity and higher power consumption of Wi-Fi, while offering better flexibility than USB's wired connection.

2. **Power Efficiency:** Bluetooth consumes significantly less power than Wi-Fi, ensuring longer operational time for battery-powered or low-power devices.

3. **Cost-Effectiveness and Ease of Integration:** Bluetooth modules like HC-05 or HC-06 are inexpensive and easy to integrate with Arduino and Raspberry Pi. The availability of libraries and strong community support reduces development time and effort.

4. **Wireless and Compact Design:** By eliminating physical cables, Bluetooth keeps the setup clean and organized, which is crucial in an EEG lab to minimize interference and maintain mobility.

5. **Scalability and Stability:** Bluetooth allows for flexible connectivity and reliable communication within its range, making it more suitable for short-range, low-bandwidth data transmission. While Wi-Fi supports higher data rates and larger networks, it is overpowered for the simple data transmission needs of this project, and USB lacks the scalability required for future system expansion.

In addition, we research that Bluetooth does not affect brain electrical signal too much, proven as in Fig. 2.1

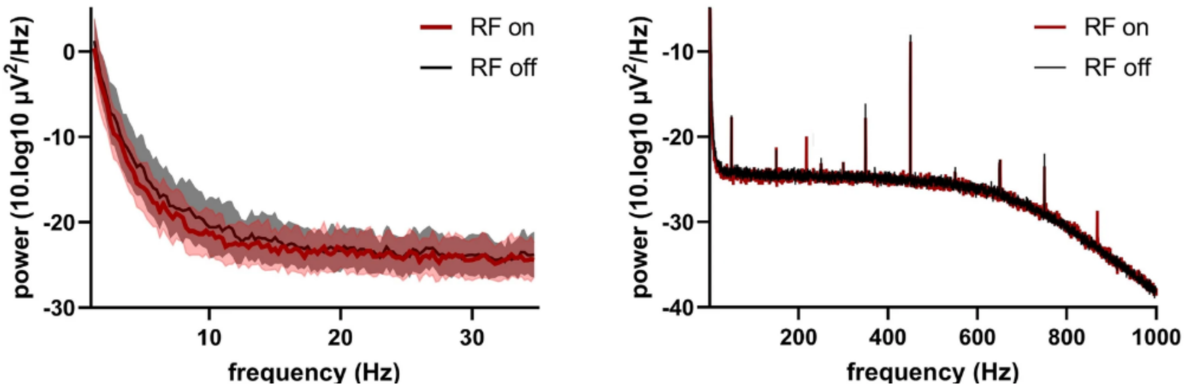

Figure 2.1 PSD plots of voluteer EEG measurement with Bluetooth on and Bluetooth off

Bluetooth operates at a frequency of 2.4 GHz with low transmission power (approximately 2.5 mW), so its impact on EEG signals is minimal. Power spectral density (PSD) measurements indicate no significant differences in the physiological frequency range of EEG signals (0–35 Hz), where brain activity occurs. However, at higher frequencies (50 Hz, 217 Hz, and their harmonics), Bluetooth can introduce minor interference. While this interference does not affect the accuracy of brain activity measurements, it is essential to ensure that EEG devices comply with EMC standards (IEC 60601-1-2) and are equipped with appropriate high-frequency filters to mitigate such interference.

2.1.2 MQTT

MQTT (Message Queuing Telemetry Transport) is a lightweight messaging protocol designed for low-bandwidth, high-latency, or unreliable networks. It follows the publish/subscribe communication model, where devices (clients) communicate through a central broker. This architecture ensures efficient data exchange without requiring a direct connection between devices, making MQTT particularly suitable for IoT (Internet of Things) applications.

The MQTT protocol operates based on three main components: publishers, subscribers, and the broker.

1. **Publisher:** A device or application that sends data (messages) to the broker. For example, a sensor can act as a publisher by sending environmental data (e.g., temperature, humidity).
2. **Subscriber:** A device or application that receives data from the broker based on its subscribed topics. For example, a server might subscribe to topics like "lab/temperature" or "lab/humidity" to monitor environmental conditions.
3. **Broker:** The central server that manages the distribution of messages between publishers and subscribers. It ensures reliable delivery and handles quality of service (QoS) levels to meet specific reliability requirements.

The communication process is efficient and highly scalable. Publishers send messages to specific "topics," and the broker forwards these messages to all subscribers interested in those topics. This decouples the publishers and subscribers, allowing flexibility in system design.

Feature	**MQTT**	**HTTP**	**CoAP**
Communication Model	Publish/Subscribe	Request/Response	Request/Response
Transport Protocol	TCP	TCP	UDP
Efficiency	Moderate	High	Low
Power Consumption	Moderate	High	Low
Reliability	High (QoS levels 0, 1, 2)	Reliable but no QoS	Lightweight reliability (ACKs)
Security	TLS/SSL	HTTPS	DTLS
Bandwidth Efficiency	High (minimal overhead, efficient for small messages)	Low (high overhead, inefficient for small messages)	Very High (minimal overhead, optimized for low bandwidth)

Table 2.2 Comparison of MQTT, HTTP, and CoAP Communication Protocols

MQTT was selected for this project due to its unique advantages over other communication protocols like HTTP and CoAP, represented in Table 2.2:

- **Low Bandwidth and Power Efficiency:** MQTT is optimized for low-bandwidth environments with minimal overhead, making it ideal for transmitting small messages like environmental data from sensors. This efficiency reduces network congestion and power consumption, critical in an IoT setup.

- **Reliable Communication with QoS Levels:** MQTT supports three levels of Quality of Service (QoS), ensuring data delivery tailored to the project's reliability requirements:
  - QoS 0: At most once (best effort).
  - QoS 1: At least once (guaranteed delivery).
  - QoS 2: Exactly once (highest reliability).
  This flexibility ensures data integrity, even in cases of unstable network connections.

- **Scalability:** The publish/subscribe model allows seamless scalability. New devices (e.g., sensors or clients) can be added without modifying the existing system, making it suitable for expanding the monitoring setup in the lab.

- **Low Power Consumption:** MQTT's lightweight nature makes it an excellent choice for battery-powered or low-power devices, like sensors connected to Arduino.

- **Security:** With support for TLS/SSL, MQTT ensures secure communication, protecting sensitive data from unauthorized access.

By using MQTT, the project benefits from a robust, efficient, and scalable communication method that is perfectly aligned with the requirements of monitoring and managing environmental conditions in the EEG lab. Its publish/subscribe model, combined with its reliability and low-resource consumption, makes it the optimal choice for this IoT-based application.

2.2 Conceptual Design

Based on the diagram as shown in Fig. 2.2, here are the tasks of each component in the system:

1. Microcontroller (Arduino Uno):

- Collects data from connected sensors.

- The sensors include:
  - Temperature & Humidity Sensor: Measures temperature and humidity levels in the room.
  - Gas Sensor: Detects CO2 or other gases in the laboratory.
  - Noise Sensor: Monitors noise levels to ensure the environment does not interfere

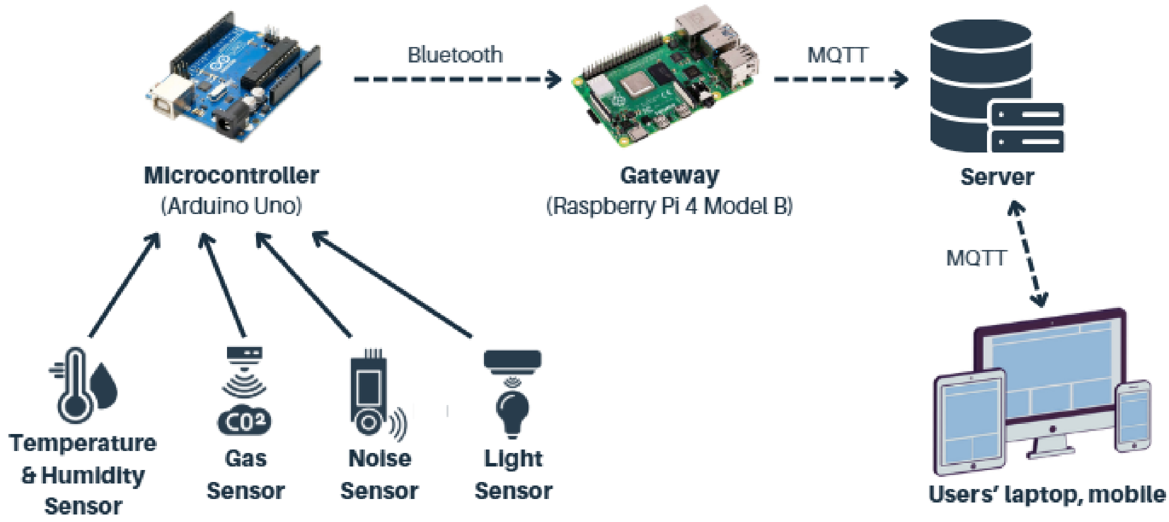

Figure 2.2 Block Diagram

with EEG signals.
- Light Sensor: Tracks light intensity to help control lighting conditions in the lab.
Sends the collected data to the Raspberry Pi via Bluetooth.

2. Gateway (Raspberry Pi 4 Model B):

- Receives data from the Arduino Uno through Bluetooth.
- Acts as an intermediary, processing and preparing the data to be sent to the server.
- Uses the MQTT protocol to send data to the server efficiently, ensuring stability and reliability.
- Can integrate basic data analysis or preprocessing functions before transmitting the data.

3. Server:

- Receives data from the Raspberry Pi via MQTT.
- Stores, analyzes, and processes data collected from the sensors.
- Triggers alerts (if needed) when data exceeds predefined thresholds (e.g., high CO2 levels, abnormal temperature).

4. Users' Laptop, Mobile Devices:

- Users access the data via an application or web interface connected to the server.

- Allows real-time monitoring of the laboratory environment.
- Receives notifications or alerts in case of environmental issues (e.g., data exceeding thresholds).

From the block diagram and tasks of each block mentioned above, the detailed flow chart is drawn in the following Fig. 2.3

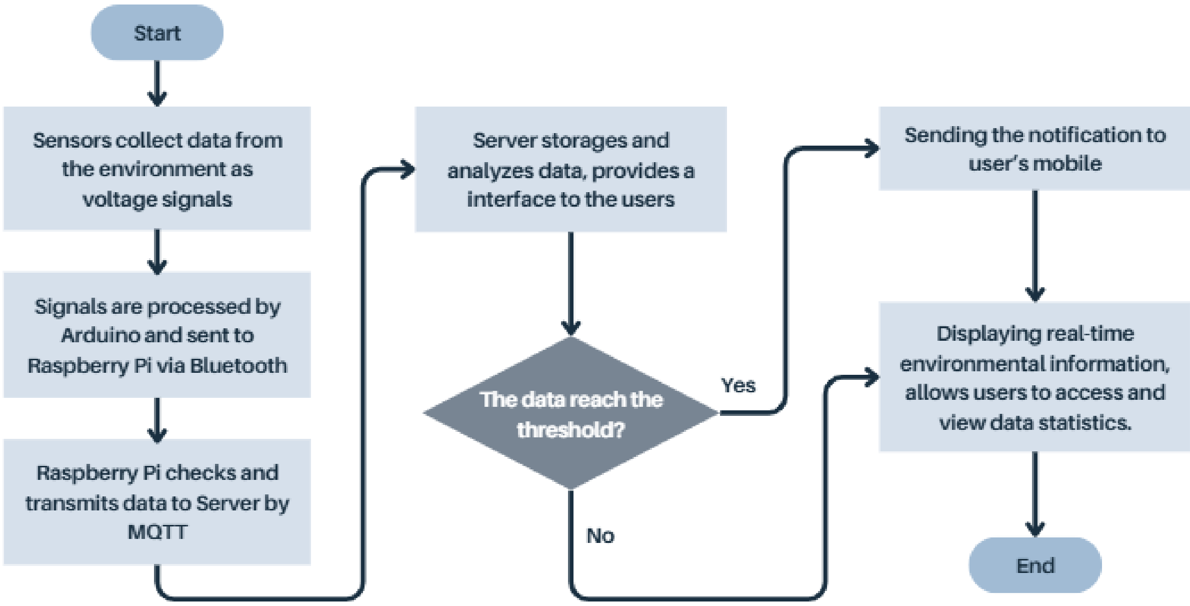

Figure 2.3 Flow Chart

The flowchart illustrates the operation of the environmental monitoring system. It begins with sensors collecting environmental data as voltage signals, which are then processed by the Arduino and sent to the Raspberry Pi via Bluetooth. The Raspberry Pi checks the data and transmits it to the server using MQTT. The server stores and analyzes the data while providing an interface for user access. A threshold check is performed on the data: if the data exceeds the predefined limits, a notification is sent to the user's mobile device; otherwise, the system displays the data in real-time for monitoring. This process ensures continuous tracking of environmental conditions while providing alerts when necessary.

CHAPTER 3. DETAILED DESIGN

3.1 Senario

3.1.1 Planning and Installation

3.1.1.1 Sensors placement

The project involves strategically placing a variety of environmental sensors in a laboratory setting to monitor factors that could influence EEG recordings. Temperature and humidity sensors are installed near the EEG recording stations to capture localized environmental conditions that may affect the accuracy and consistency of the readings. These sensors provide real-time data on the surrounding environment, ensuring that fluctuations in temperature or humidity do not interfere with the equipment's performance or the quality of the recorded signals.

Air quality sensors are positioned near ventilation systems and patient areas to monitor the concentration of airborne pollutants, such as carbon dioxide, particulate matter, and volatile organic compounds. Maintaining optimal air quality is crucial for the health and comfort of both patients and researchers. These sensors help ensure that the lab environment remains conducive to both the participants' well-being and the integrity of the EEG data collected.

Noise and light sensors are distributed across the lab, focusing on areas where disturbances are most likely to occur. Noise sensors are placed in close proximity to potential sources of interference, such as air conditioning units, equipment, or other machinery. By monitoring sound levels, these sensors help identify unwanted auditory disturbances that could impact the EEG signals. Similarly, light sensors are deployed in key areas to detect fluctuations in lighting conditions, which may disrupt the EEG signal quality. These sensors help maintain a controlled, stable environment, minimizing external factors that could compromise the reliability of the data collected during EEG recordings.

Together, these sensors provide a comprehensive environmental monitoring system that contributes to the overall quality and accuracy of EEG data, enabling researchers to account for and mitigate potential sources of interference in their experiments.

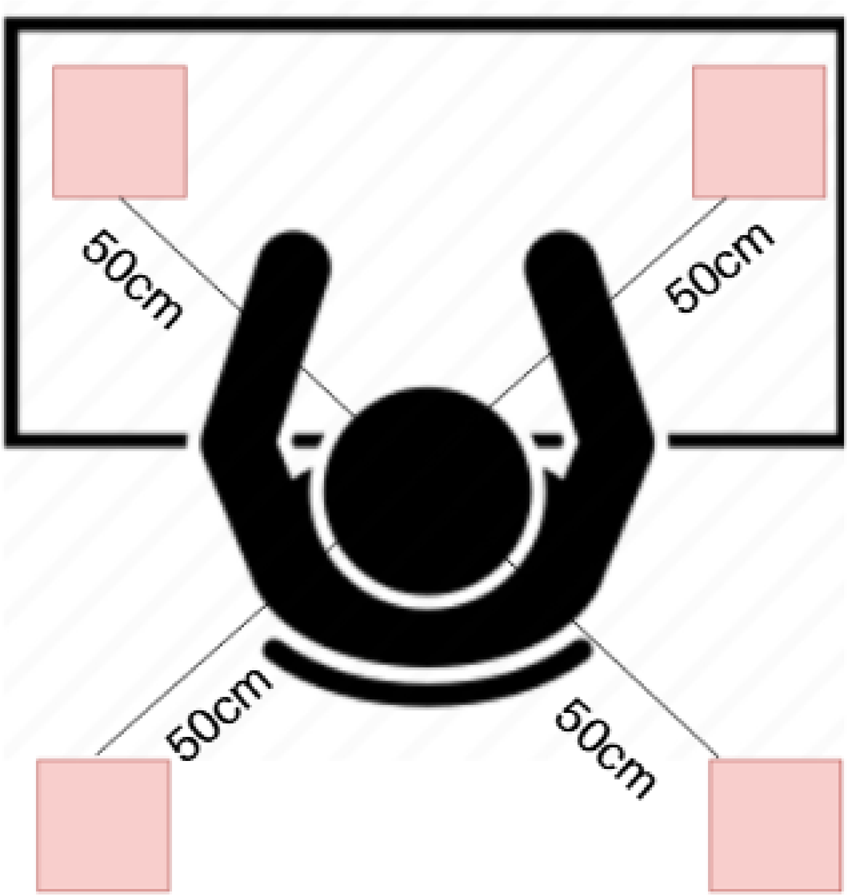

Figure 3.1 Placement of IoMT nodes

3.1.1.2 System Integration

The sensors are calibrated to ensure accurate readings of environmental parameters like temperature, humidity, CO2, CO, noise, and light. Calibration involves testing against known standards to eliminate errors. After calibration, the sensors are connected to the IoMT gateway, which consolidates and synchronizes data from multiple sensors. The gateway uses reliable communication protocols (e.g., Wi-Fi, Zigbee) to ensure smooth data flow.

The IoMT gateway securely transmits data to the server using encryption protocols like TLS or SSL to protect against unauthorized access. Authentication ensures only authorized devices can exchange data. In case of network disruption, the gateway stores data locally and transmits it once connectivity is restored. This ensures continuous, reliable data collection while maintaining security and integrity.

3.1.2 Monitoring

a. Sensor Data Collection

The sensors collect data only when triggered by pressing a button during the experiment. This ensures data is recorded only when needed, optimizing power usage and storage.

b. IoMT Gateway Data Collection and Cloud Updates

The IoMT gateway collects data from the sensors and transmits it to the cloud platform every few seconds. This frequent update ensures real-time monitoring of environmental conditions during the experiment, while also storing the data for future analysis. The gateway ensures proper data formatting and synchronization before transmission.

3.1.3 Data Analysis and Visualization

a. Cloud Platform Data Processing and Anomaly Detection

The cloud platform serves as the central hub for processing the data collected by the sensors. Once the data is transmitted from the IoMT gateway, it is stored and analyzed in real-time. The platform applies advanced machine learning algorithms to detect anomalies in the environmental parameters, such as sudden spikes in temperature, humidity, CO2 levels, or noise. These algorithms are trained on historical data to recognize patterns and establish normal ranges for each parameter. When the platform detects any data points that fall outside of these expected ranges, it flags them as potential anomalies. This automated detection system helps identify issues that could impact the quality of the EEG data or pose health risks, allowing for quick intervention and corrective actions.

b. Analytics Dashboard

The analytics dashboard provides a comprehensive and user-friendly interface for viewing real-time and historical data. Key information displayed on the dashboard includes:

- Current Conditions: The dashboard shows the current values of the environmental parameters in a clear and organized manner, such as:
  - Temperature: 23°C
  - Humidity: 50
  - Noise: 35 dB
  - CO2: 400 ppm
  - Light: 300 lux

  These values provide a snapshot of the current environmental conditions in the experiment room, ensuring that all parameters remain within optimal ranges for EEG data accuracy.

- Trends and Predictions: he dashboard also highlights trends and potential future deviations based on historical data. By analyzing past data, the platform can predict possible fluctuations in environmental conditions, such as rising CO2 levels or increasing noise, and provide alerts if these trends indicate that conditions may soon exceed acceptable thresholds. This predictive capability allows for proactive monitoring, enabling users to take preventive actions before any significant impact on the experiment occurs.

The dashboard thus acts as both a real-time monitoring tool and a forecasting platform, providing valuable insights into the environmental conditions and allowing users to make data-driven decisions to maintain an ideal setting for EEG measurements.

3.1.4 Threshold Alerts and Automation

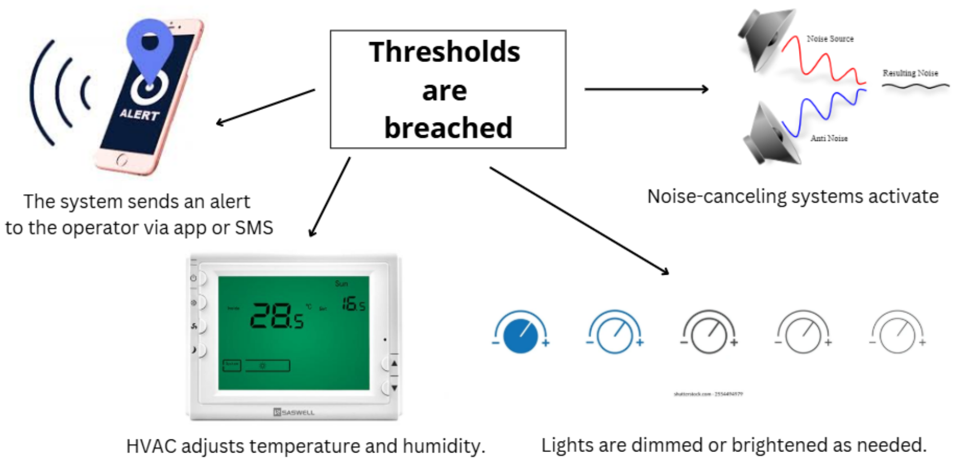

Figure 3.2 Threshold Alerts and Automation

3.1.5 Integration with EEG Data

3.2 Sensor Selection

3.2.1 MQ-135 Gas Sensor Module

Figure 3.3 MQ-135 Gas Sensor Module

Wide Detection Range: Operates effectively across a broad input voltage range, ideal for diverse applications like voltage monitoring and signal detection.

Low Voltage & Current Requirements: Runs on 2V–36V with minimal power consumption, perfect for battery-powered systems.

Analog & Digital Outputs: Offers flexible outputs for interfacing with both analog and digital circuits or microcontrollers.

Cost-Effective: Affordable yet reliable, making it suitable for commercial, industrial, and hobbyist projects.

3.2.2 LM393 Sound Detection Sensor Module

Wide Detection Range: Operates effectively across a broad input voltage range, ideal for diverse applications like voltage monitoring and signal detection.

Low Voltage Current Requirements: Runs on 2V–36V with minimal power consumption, perfect for battery-powered systems.

Analog Digital Outputs: Offers flexible outputs for interfacing with both analog and digital circuits or microcontrollers.

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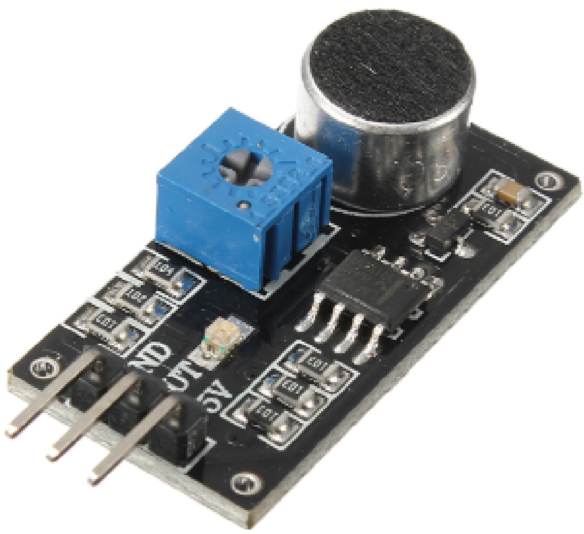

Figure 3.4 LM393 Sound Detection Sensor Module

3.2.3 BH1750 Light Intensity Sensor

Wide Detection Range: Measures ambient light from 1 lux to 65,535 lux, suitable for low-light indoor to bright outdoor conditions.

Voltage and Current Requirements: Operates at 2.4V–3.6V with low power consumption, ideal for battery-powered and IoT devices.

Digital Output: Provides precise measurements via an I²C interface, simplifying integration with microcontrollers without the need for ADCs.

Cost-Effective: Offers reliable performance at an affordable price, reducing implementation costs for a wide range of applications.

Figure 3.5 BH1750 Light Intensity Sensor

3.2.4 DHT11 Temparature & Humidity Sensor

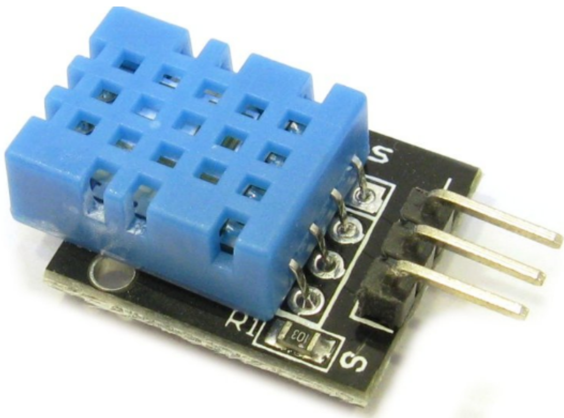

Figure 3.6 DHT11 Temparature & Humidity Sensor

Wide Detection Range: Measures temperature from 0°C to 50°C (±2°C accuracy) and humidity from 20% to 90% RH (±5% accuracy).

Low Power Requirements: Operates on 3.3V–5V, consuming only 2.5 mA during use and 100 μA in standby mode.

Digital Output: Provides a simple single-wire digital signal, eliminating the need for an external ADC.

Cost-Effective: Affordable and reliable, ideal for budget projects and basic environmental monitoring.

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