IOT-BASED WIRELESS THERMOMETER FOR REMOTE TEMPERATURE MONITORING USING MICROCONTROLLER

by

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A report submitted in partial fulfillment of the requirements for the degree
of
Bachelor of Engineering (Computer Engineering)

Faculty of Electronic Engineering & Technology
UNIVERSITI MALAYSIA PERLIS

2025

UNIVERSITI MALAYSIA PERLIS

DECLARATION OF REPORT

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Date of Birth	:	20 JANUARY 2001
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This project report has been found satisfactory in terms of scope, quality and presentation as partial fulfilment of the requirement for the Bachelor of Engineering (Computer Engineering) in Universiti Malaysia Perlis (UniMAP).

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ACKNOWLEDGEMENT

Firstly, I would like to extend my heartfelt gratitude to my project supervisor, Assoc. Prof. Ts. Dr. Mohammad Shahrazel Razalli, for his invaluable advice, guidance, and support throughout the design and writing phases of this project. His mentorship has enriched my knowledge greatly, and I have also enhanced my problem-solving skills as a result.

I am also deeply appreciative of the dedicated Final Year Project coordinators, lecturers, and staff of the School of Computer and Communication, University Malaysia Perlis, for their cooperation, steadfast support, and the crucial information and guidance provided during the preparation and compilation of this project.

My sincere thanks go to my beloved family for their unwavering moral support and prayers, which have helped me navigate the challenges of this project smoothly. Their encouragement and assistance have been instrumental throughout my undergraduate journey.

Finally, I wish to acknowledge and thank my friends who volunteered for this project. Their participation made the project testing possible, and I am grateful for their patience and dedication during every procedure. Their encouragement and support from the beginning of the semester have been a source of motivation, enabling me to carry out this final year project successfully.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Termometer Tanpa Wayar Berasaskan IoT untuk Pemantauan Suhu Jarak Jauh

ABSTRAK

Evolusi Internet of Things (IoT) telah meningkatkan kemampuan untuk memantau keadaan persekitaran dari jarak jauh. Projek ini berpusat pada pembangunan termometer tanpa wayar berasaskan IoT untuk pemantauan suhu secara masa nyata. Sistem ini bertujuan untuk mengatasi cabaran yang dihadapi oleh kaedah pemantauan tradisional, seperti pengambilan bacaan secara manual dan ketidakcekapan dalam integrasi data. Dengan menggunakan mikropengawal ESP32 dan sensor suhu SHTC3, sistem ini mengumpul data suhu yang tepat dan menghantarnya ke platform awan seperti ThingSpeak dan Google Sheets untuk penyimpanan, visualisasi, dan analisis tren. Tambahan pula, bot Telegram memberikan amaran masa nyata apabila ambang suhu melebihi had, memudahkan pengguna untuk bertindak segera. Projek ini menggabungkan komponen perkakasan dan perisian untuk membangunkan penyelesaian yang kukuh dan boleh diskalakan. Aspek perkakasan merangkumi pengurusan kuasa yang cekap untuk membolehkan operasi yang berpanjangan, manakala perisian tertumpu pada pengambilan data, pemprosesan, dan visualisasi berasaskan awan yang mesra pengguna. Ujian dan pengesahan dijalankan melalui simulasi dan persekitaran dunia sebenar untuk mengesahkan kebolehpercayaan dan keberkesanan sistem. Hasilnya menunjukkan kemampuan sistem ini untuk memantau secara masa nyata, menyimpan data dengan cekap, dan memberikan notifikasi tepat pada masanya, menjadikannya sesuai untuk aplikasi dalam penjagaan kesihatan, pertanian, dan automasi rumah. Termometer berasaskan IoT ini meningkatkan kemudahan dan kecekapan operasi serta membantu dalam membuat keputusan dengan menyediakan data persekitaran yang tepat. Ia menawarkan cara yang kos efektif dan cekap tenaga untuk pemantauan suhu jarak jauh.

IoT -Based Wireless Thermometer for Remote Temperature Monitoring

ABSTRACT

The evolution of the Internet of Things (IoT) has greatly improved the capability to monitor environmental conditions from a distance. This project centers on creating an IoT-based wireless thermometer for real-time temperature monitoring. The system aims to overcome the challenges posed by traditional monitoring methods, such as manual readings and inefficiencies in data integration. Utilizing an ESP32 microcontroller and an SHTC3 temperature sensor, the system gathers precise temperature data and transmits it to cloud platforms like ThingSpeak and Google Sheets for storage, visualization, and trend analysis. Furthermore, a Telegram bot delivers real-time alerts when temperature thresholds are surpassed, facilitating prompt user intervention. The project merges hardware and software components to develop a robust and scalable solution. The hardware aspect incorporates efficient power management to enable extended operation, while the software concentrates on data acquisition, processing, and user-friendly cloud-based visualization. Testing and validation were performed through simulations and real-world environments to confirm the system's reliability and effectiveness. The results showcase the system's ability to monitor real-time, efficiently store data, and make timely notifications, making it applicable in healthcare, agriculture, and home automation. This IoT-based thermometer improves convenience and operational efficiency and aids decision-making by providing accurate insights into environmental data. It presents a cost-effective and energy-efficient means of remote temperature monitoring.

CHAPTER 1 : INTRODUCTION

1.1 Project Overview

IoT refers to the connection of devices and the Internet, and the traditional monitoring systems are also evolving, bringing enhanced convenience and operational efficiency. It focuses on the design and implementation of a wireless IoT-based thermometer for the remote monitoring of temperature (Gada et al., 2021b).

The main objective includes designing a unit that could be connected to internet and can communicate with the cloud to store and monitor the data. With this, users have the benefit of a creating an automatic warning system that sends real-time alerts for temperature changes.

According to them, additionally this project will also involve an assessment of how well the device works in order to ensure that it can meet certain standards for accuracy and reliability.

1.2 Problem Statement

Temperature monitoring is essential in sectors such as healthcare, agriculture, and home automation, where keeping optimal conditions is important for safety, product integrity, and the durability of equipment. Traditional approaches, often relying on manual measurements or wired systems, are ineffective and prone to human mistakes. These methods typically do not offer real-time monitoring and alert capabilities, heightening the risk of problems such as product spoilage, safety risks, and financial setbacks, particularly in vital areas like cold storage, greenhouses, or healthcare settings.

Moreover, many current systems face challenges in data integration and analysis, complicating the process of detecting patterns or taking preventive actions. In the absence of immediate alerts for temperature variations, significant changes may be overlooked, potentially resulting in severe repercussions.

To resolve these challenges, a wireless, cloud-based temperature monitoring solution is necessary. This type of system would deliver ongoing real-time data, provide prompt alerts for any deviations from established thresholds, and preserve historical data for trend analysis. This strategy would support improved environmental management, boost decision-making, and assist in averting expensive interruptions.

1.3 Project Objective

The main goals of this project include:

1. Design and build an IoT-based wireless thermometer for remote temperature monitoring with real-time cloud-based data access and storage.

2. Develop a user-friendly web dashboard for monitoring, data analysis, and managing alerts when temperature exceeds set thresholds.

1.4 Project Scope

The project incorporates the design and development of a wireless thermometer system based on IoT, incorporating both hardware and software elements. The hardware component includes choosing an appropriate temperature sensor, a microcontroller, and power management capabilities to enhance battery longevity. The software module is cantered on developing firmware to collect and send temperature information to the cloud via Wi-Fi and communication protocols like MQTT or HTTP. Moreover, cloud integration (e.g.: ThingSpeak) is used for data storage and retrieval, facilitating remote temperature tracking.

The initiative focuses on creating an intuitive web dashboard for monitoring temperature in real time, analysing historical data, and managing alerts. Ultimately, a fundamental system assessment is performed to evaluate data precision, transmission dependability, energy efficiency, and general usability, with the device enclosed in a weather-resistant casing appropriate for indoor and outdoor applications.

CHAPTER 2 : LITERATURE REVIEW

2.1 Introduction

This chapter introduces the fundamental concepts and existing technologies relevant to the IoT-Based Wireless Thermometer for Remote Temperature Monitoring. It provides a detailed understanding of the theories and practices that guide the project, drawing on journal articles, research papers, and other scholarly references. The review highlights advancements in IoT systems, sensor networks, and temperature monitoring solutions, establishing the foundation for this project.

2.2 Overview

The overview of this sub-chapter explains about the basics of fundamental theories and ideas that is used in the project. The project uses the concept of Internet of Things (IoT), sensor networks, gateway, cloud and smart devices which are essential for the design and development of the IoT-based wireless thermometer.

2.2.1 Internet of Things (IoT)

The Internet of Things (IoT) refers to a system of interconnected devices capable of communicating and exchanging data with other IoT devices and the cloud. These devices, equipped with technologies like sensors and software, range from mechanical and digital machines to everyday consumer items. IoT encompasses a broad spectrum of applications, from household gadgets to advanced industrial equipment. Businesses across various sectors are leveraging IoT to boost operational efficiency, enhance customer experiences, support better decision-making, and add value to their operations (*What Is IoT (Internet of Things)? | Definition from TechTarget*, n.d.).

Through IoT, data can be shared over a network without the need for direct human involvement, either between individuals or between humans and computers.

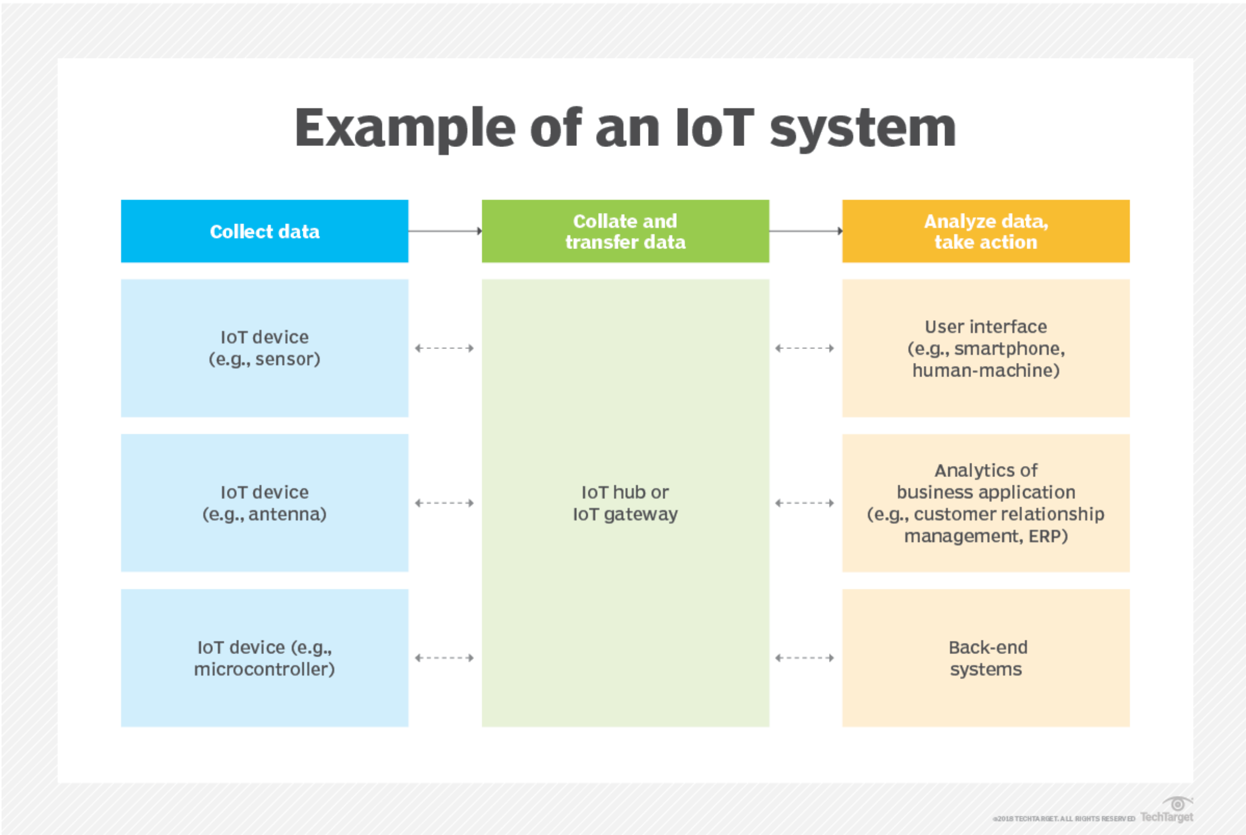


Figure 2.1: IoT system (What Is IoT (Internet of Things)? | Definition from TechTarget, n.d.)

2.2.2 SENSOR NETWORK

The sensor network is vital to the project, functioning as a method to gather data from devices or machines. Celebrated for its reliability, accuracy, adaptability, cost-effectiveness, and simple installation, the sensor network effectively performs tasks such as data collection, information analysis, and providing a reliable monitoring system (*What Is IoT (Internet of Things)? | Definition from TechTarget*, n.d.). In this initiative, the sensor network is essential for retrieving temperature data through the thermometer, enabling users to conveniently access this information at any time.

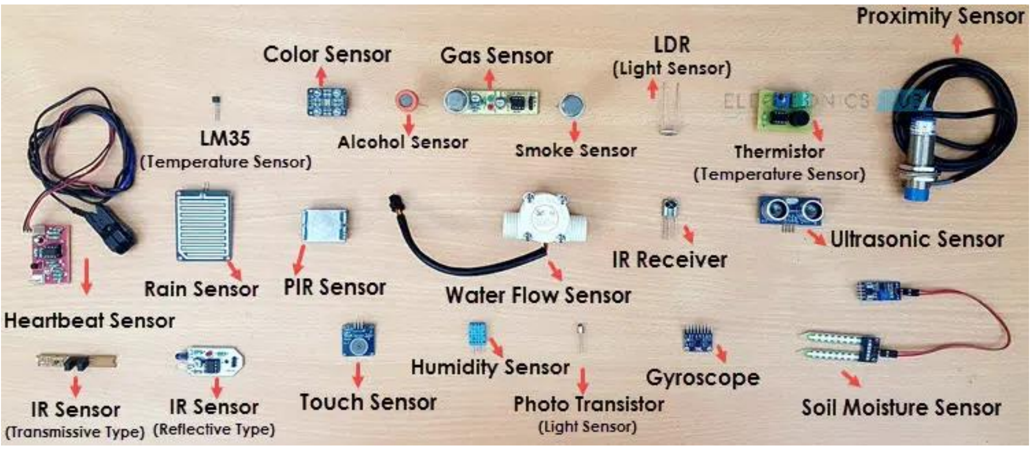


Figure 2.2: Different type of sensors (What Is A Sensor, Different Types Of Sensors, n.d.).

2.3 Previous Project

This sub-chapter consist of review of previous projects that related to the IoT-based remote temperature monitoring.

2.3.1 Remote Temperature Monitoring Using MQTT for IoT Smart Homes (Quamara et al., 2019)

This paper was authored by Megha Quamara, B. B. Gupta, and Shingo Yamaguchi. The project explores an IoT – based temperature monitoring system through using MQTT for real-time communication and data sharing in smart homes. The proposed system integrates temperature sensors with a microcontroller that connects to an MQTT broker, enabling real-time temperature data transmission to the cloud. A web-based application is deployed to visualize the data and issue alerts when temperature thresholds are breached.

Implementation and result:

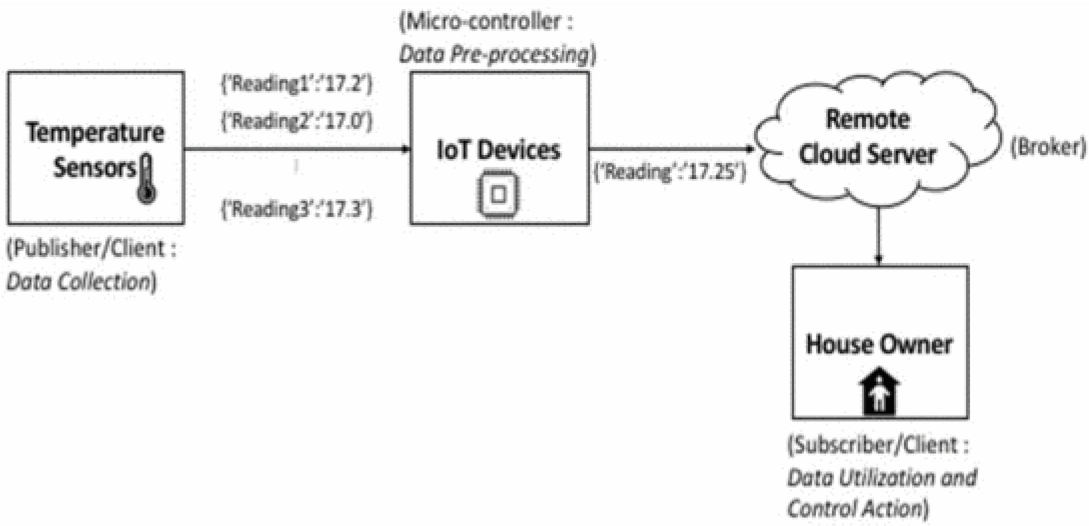


Figure 2.3: Proposed system (Quamara et al., 2019).

Table 2.1 INITIAL PARAMETER SETTING (Quamara et al., 2019)

Parameter	Values		
Load Test Name	LoadTest1	LoadTest2	LoadTest3
# of messages to publish		10/20	
Topic		Home/LivingRoom/Temperature	
Protocol		Ws	
Run time (seconds)		5	
QoS	0	1	2
Time Out (seconds)		30	
# of instances to run		2	

Table 2.2 LOAD TEST RESULTS (Quamara et al., 2019)

Instances	Published Time (s)	QoS Time (s)
	LoadTest1 (QoS = 0)	
Instance1	4.5340 / 4.8080	4.5350 / 4.8090
Instance2	4.5290 / 4.8060	4.5300 / 4.8070
	LoadTest2 (QoS = 1)	
Instance1	4.5240 / 4.8130	5.4270 / 5.4370
Instance2	4.5250 / 4.8120	5.4260 / 5.4360
	LoadTest3 (QoS = 2)	
Instance1	4.5200 / 4.7980	4.5200 / 4.7980
Instance2	4.5200 / 4.7980	4.5200 / 4.7980

The project emphasizes efficient communication, lightweight data transfer, and real-time accessibility. It aligns well with the requirements of IoT-based smart home systems. Through usage of MQTT, the system reduces network bandwidth usage and ensures fast delivery of temperature updates, even in constrained environments.

2.3.2 IoT-Based Temperature Monitoring System (Gada et al., 2021b)

The research by Gada et al. (2021) analyzes a network set up for monitoring temperatures at distant locations using IoT. This network connects things for the data collected by temperature sensors with a microcontroller. The data is sent to some cloud-based platform for visualization with a touch of reality. A dashboard, which has been designed to be user-friendly, allows the end-user tracking of variations and trends in temperature over time. It highlights data acquisition and presentation reliability.

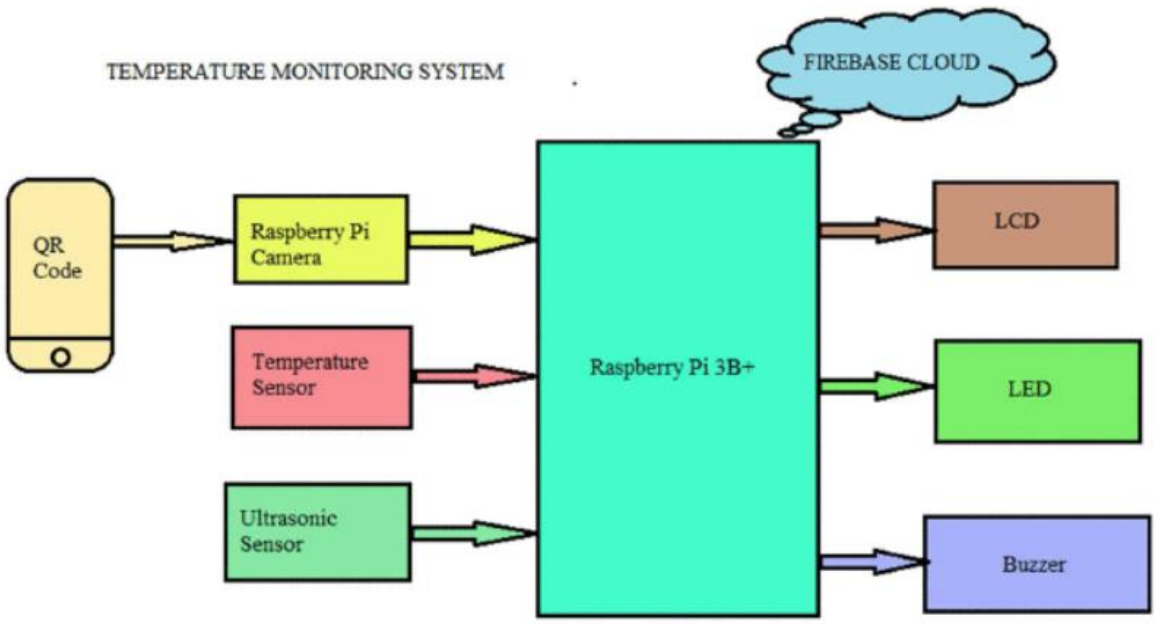


Figure 2.4: Block diagram temperature monitoring system (Gada et al., 2021b)

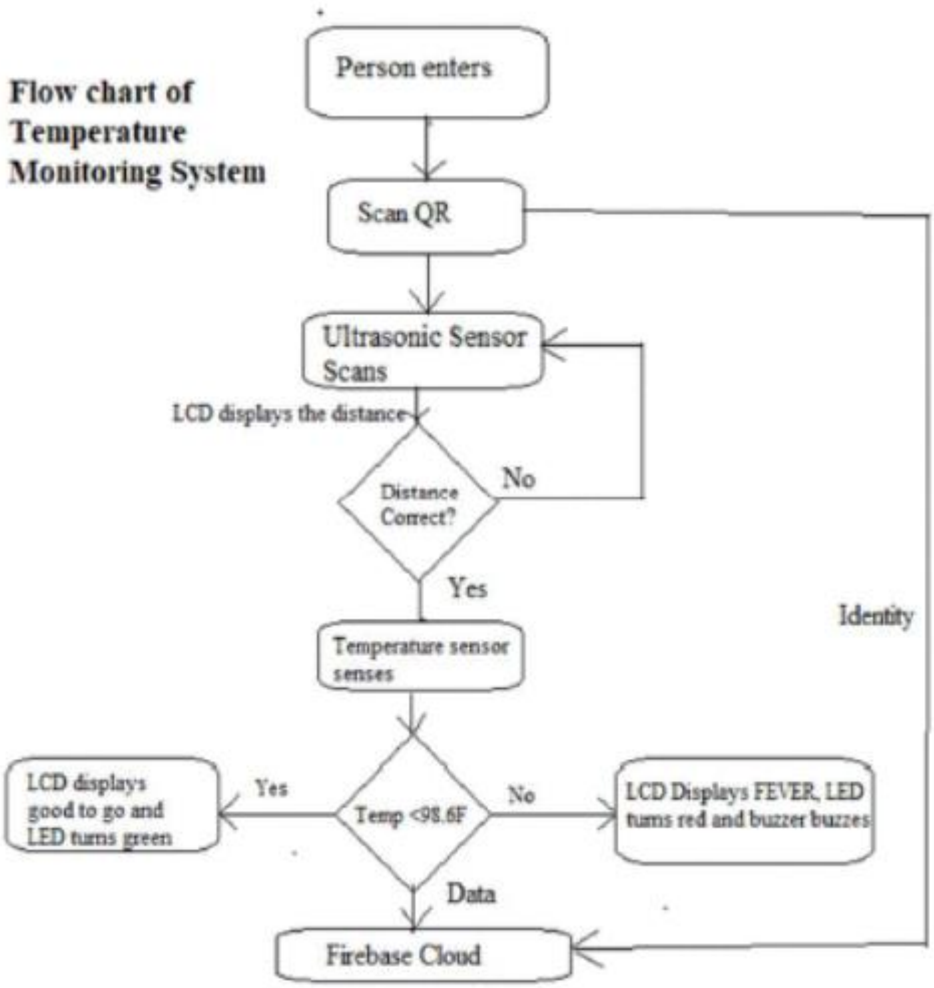


Figure 2.5: Flow chart of temperature monitoring system (Gada et al., 2021b)

Figure 2.6: Look of temperature monitoring system (Gada et al., 2021b)

The deployment of this IoT-based system enables real-time data gathering, remote access, and the potential for integration with additional monitoring parameters. However, despite the system's strengths in ensuring dependable data logging and comprehensive visualization, it also presents some limitations, including the requirement for a stable internet connection and the complexity of initial setup. Additionally, it lacks built-in alert systems, thereby limiting it to applications that do not specifically necessitate an immediate reaction to temperature variations. In summary, this system represents a significant advancement in temperature monitoring solutions, leveraging Internet of Things technology to provide effective and efficient monitoring capabilities.

2.3.3 A ThingSpeak IoT on Real-Time Room Condition Monitoring System(Razali et al., 2020)

This paper investigates the creation of a real-time monitoring system for room conditions implemented on the ThingSpeak Internet of Things (IoT) platform. The research emphasizes the use of energy-efficient sensors to assess environmental factors like temperature and humidity in indoor areas.

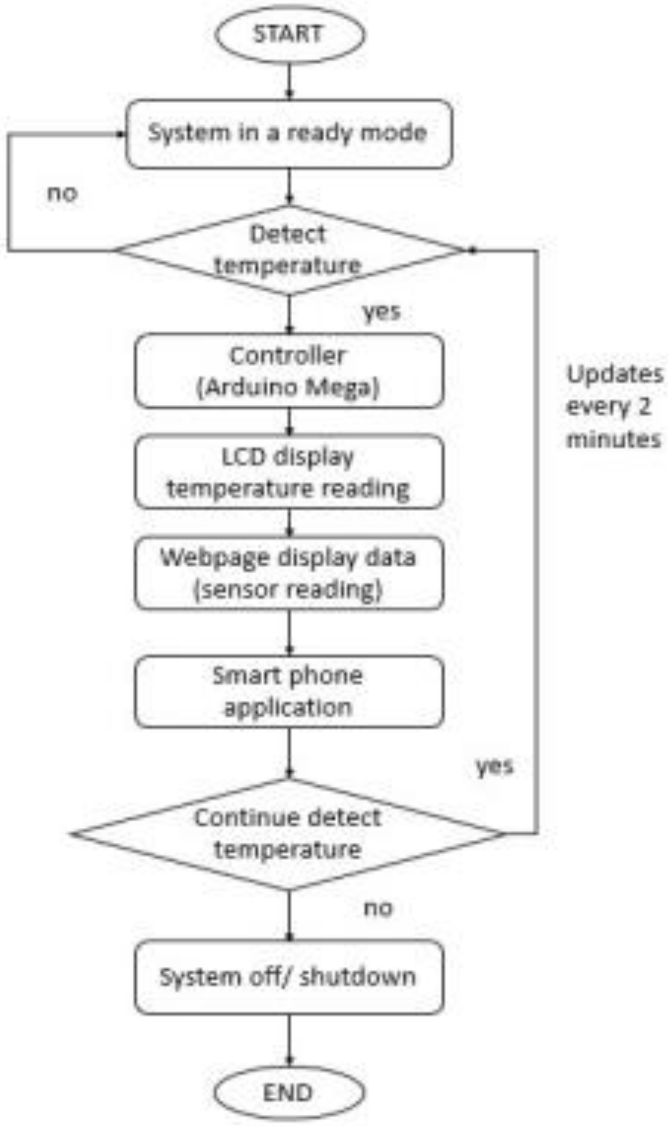


Figure 2.7: System's flowchart (Razali et al., 2020)

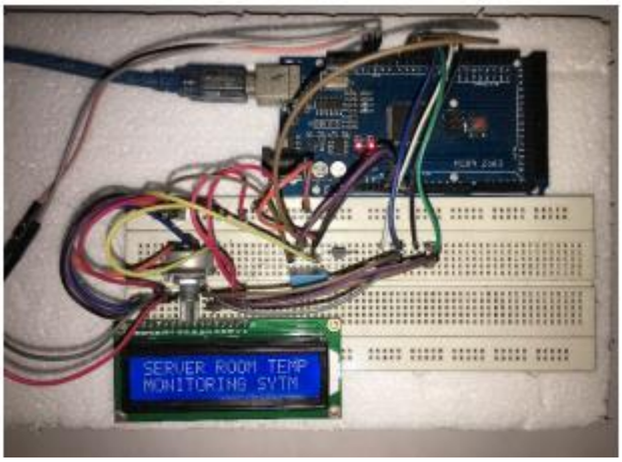


Figure 2.8: The hardware of the Room Monitoring System (Razali et al., 2020)

These sensors continuously send data to the ThingSpeak cloud for processing and visualization, enabling users to observe changes as they happen. The results of the ThingSpeak are shown in Figure 2.9.

Figure 2.9: Temperature and Humidity data collection from ThingSpeak website (Razali et al., 2020)

The system is designed with simplicity in installation, cost effectiveness, and energy conservation in mind, making it suitable for home and office uses. The study emphasizes the platform's capability to enable live monitoring, presenting a simple yet efficient method for controlling indoor environmental conditions. This research highlights the smooth integration of IoT technology with data visualization platforms, providing users with prompt and accessible updates.

Nevertheless, the system is mainly intended for indoor settings and is not robust enough for outdoor or industrial use, which requires more durable and scalable solutions. Plus, it lacks integrated alert mechanisms, limiting its use in cases where immediate responses to temperature anomalies are critical. Despite these challenges, the paper illustrates the potential of IoT in improving environmental monitoring with practical and user-friendly approaches tailored to varying needs.

2.3.4 Internet-of-Things Based Smart Temperature Monitoring System (Rao & Prema, 2018)

The paper "Internet-of-Things Based Smart Temperature Monitoring System" by Rao and Prema (2018) presents an IoT-enabled system for temperature and humidity monitoring in applications such smart homes, industrial settings, and agriculture. The system combines cloud platforms for data storage and visualization, microcontrollers for processing, and sensors for data gathering. The design incorporates real-time alert features to notify users when temperature or humidity thresholds are breached, allowing timely interventions to prevent adverse outcomes.

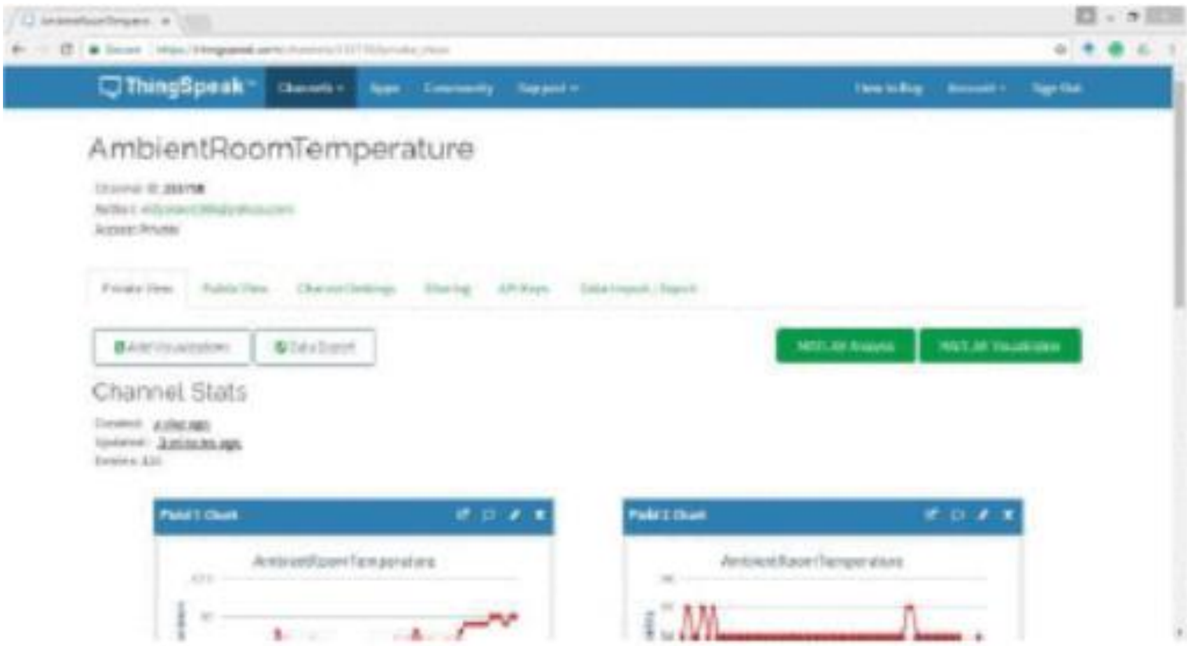


Figure 2.10: Temperature and humidity visualization in thingspeak (Rao & Prema, 2018)

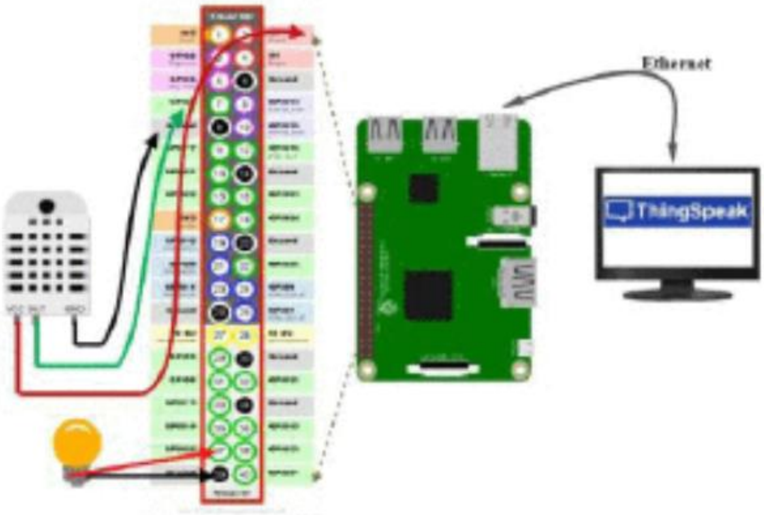


Figure 2.11: Proposed IoT model (Rao & Prema, 2018)

There is a slightly common as the project of the ‘A ThingSpeak IoT on Real Time Room Condition Monitoring System’ by (Razali et al., 2020). The difference is that instead of using Arduino board, it uses Raspberry pi 3 model. Rao and Prema's project, which uses a Raspberry Pi 3, shows how to balance scalability and performance, making it a flexible solution for a range of IoT applications. Compared to Arduino-based systems, this difference demonstrates the project's potential to support more computationally intensive jobs and its flexibility in a variety of environmental circumstances. But the cons are that the Raspberry pi required more power and consume the more battery life compared to Arduino board or ESP 32.

Overall, the project shows the demonstration on how IoT-based monitoring systems can enhance decision-making through real-time data and alert systems, showcasing their potential to improve efficiency and reliability in temperature-sensitive applications.

2.3.5 An IoT-Based Real-Time Weather Monitoring System Using Telegram Bot and Thingsboard (Bestari & Wibowo, 2023)

The paper "An IoT-Based Real-Time Weather Monitoring System Using Telegram Bot and ThingsBoard" by Bestari and Wibowo (2023) introduces a weather monitoring system that uses IoT technology for real-time data collection and user interaction. The system incorporates ThingsBoard for data visualization and analysis, a Telegram bot for real-time user notifications, and weather sensors for data collection.

The project uses a more precision temperature sensor which is SHTC3, which is more accurate than DHT11 / DHT22. This enhanced accuracy ensures the system's reliability for applications requiring precise environmental monitoring. The circuit diagram of the project are shown in Figure 2.12.

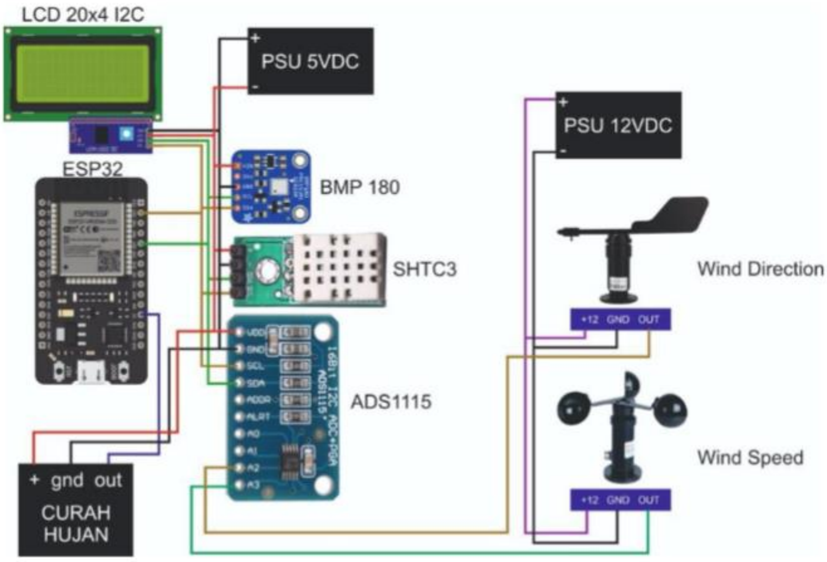


Figure 2.12: Diagram of Device Wiring (Bestari & Wibowo, 2023)

The data collected by the sensor is sent to ThingsBoard platform for storage, visualization, and trend analysis. Furthermore, the Telegram Bot provides a real-time alerts hat improve user engagement and responsiveness.

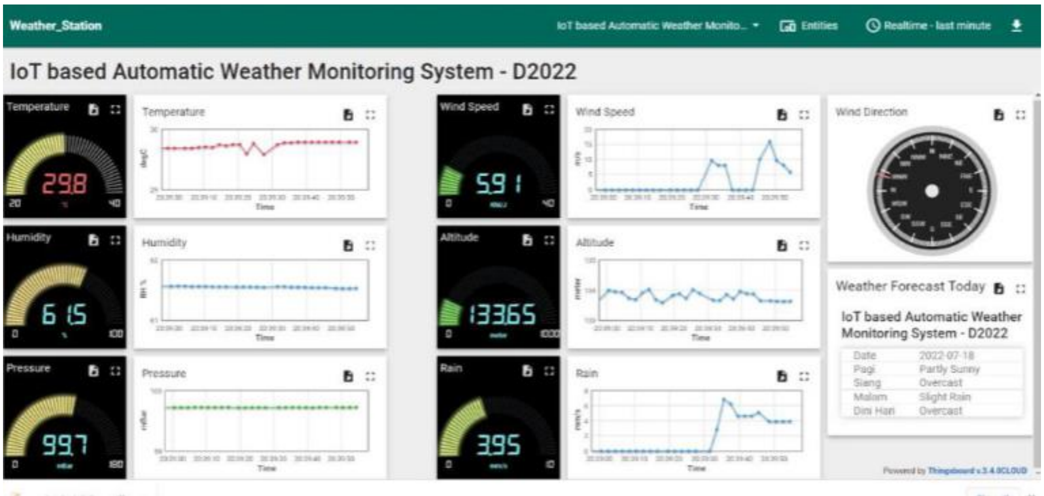


Figure 2.13: Result from ThingsBoard (Bestari & Wibowo, 2023)

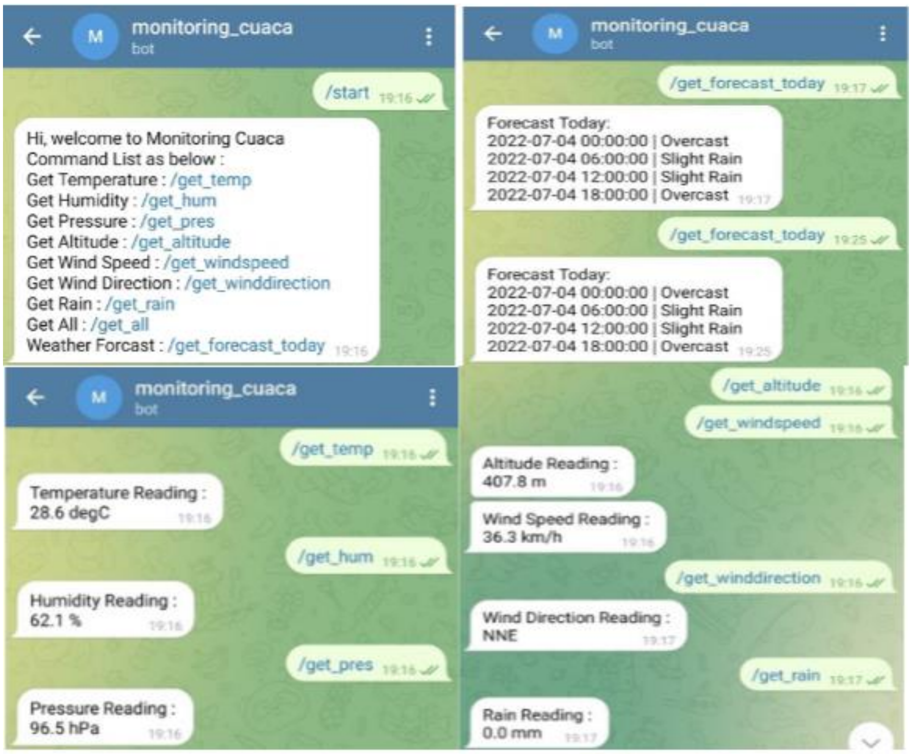


Figure 2.14: Result from TelegramBot (Bestari & Wibowo, 2023)

Overall, to satisfy the demands of applications in smart city management, environmental monitoring, and agriculture, the project's design focuses on fusing precise sensing technology with cutting-edge notification and visualization capabilities. Although there are user-centric advantages to the combination of Telegram and ThingsBoard, the system's total complexity and need on dependable internet connectivity may make adoption difficult in rural or isolated locations.

2.3.6 Smart IoT based Human Well-being Monitoring in Health Care System (Elankavi et al., 2022)

The paper by (Elankavi et al., 2022) presents a Smart IoT-based system designed to monitor human well-being in healthcare environments. Through IoT technology, the system provides a way measure critical health parameters such as body temperature, heart rate, room temperature, and levels of carbon dioxide (CO_2) and carbon monoxide (CO) in the environment.The data collected is then transmitted to a cloud-based platform, allowing healthcare professionals to remotely monitor and analyze patient health conditions.

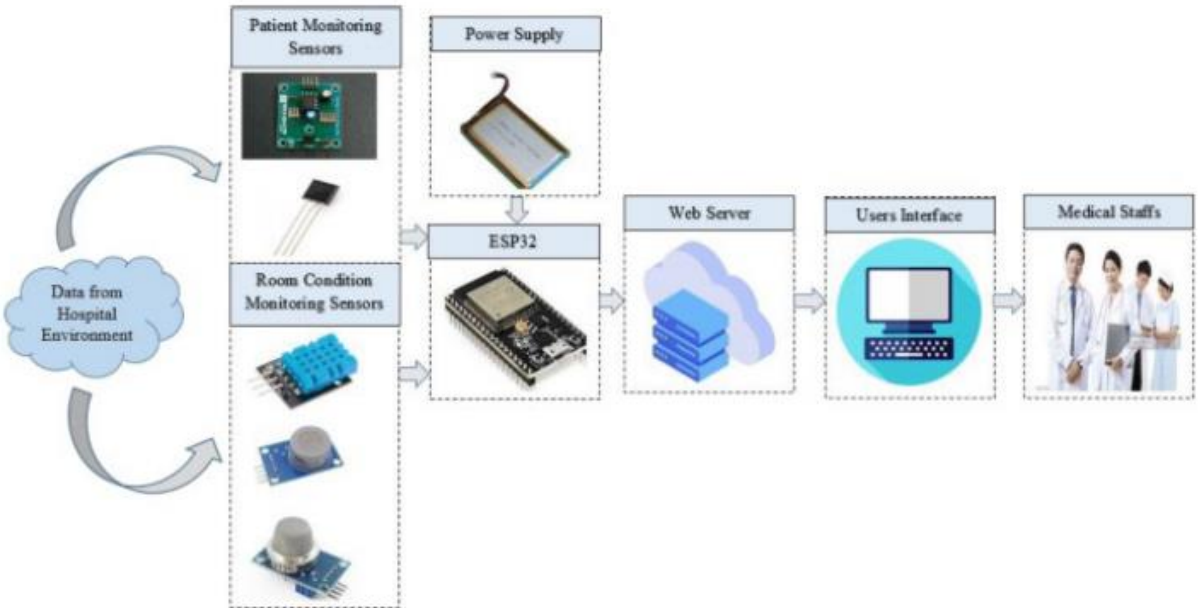


Figure 2.15: Human Monitoring System (Elankavi et al., 2022)

The architectural design incorporates a range of sensors for accurate data acquisition, such as heart rate monitors, body temperature sensors, and environmental sensors. This system is engineered for scalability, enabling the simultaneous monitoring of numerous individuals, with applications that extend from personal health monitoring to extensive hospital administration.

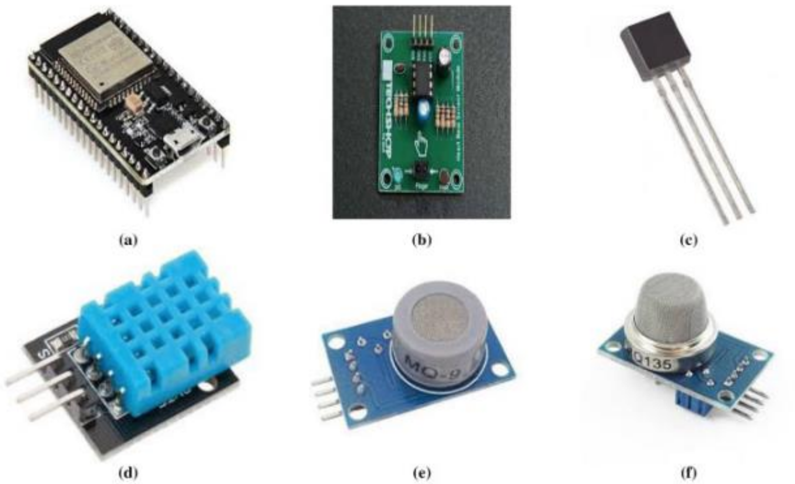


Figure 2.16: Various Sensors employed to monitor human body (Elankavi et al., 2022)

The results from the study highlight the system's ability to effectively monitor pulse rates and temperature trends across different individuals. Both the Figure 2.17 and Figure 2.18 shows the data analysis capabilities. While Figure 2.19 demonstrates its applicability in healthcare settings.

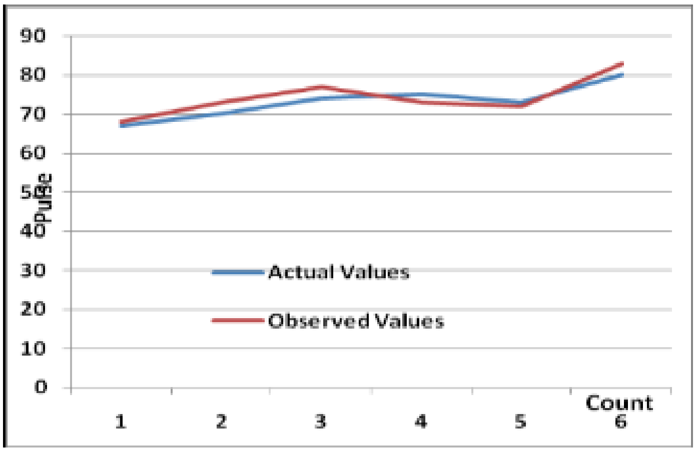


Figure 2.17: Pulse vs Number of persons (Elankavi et al., 2022)

Figure 2.18: Temperature vs Number of persons (Elankavi et al., 2022)

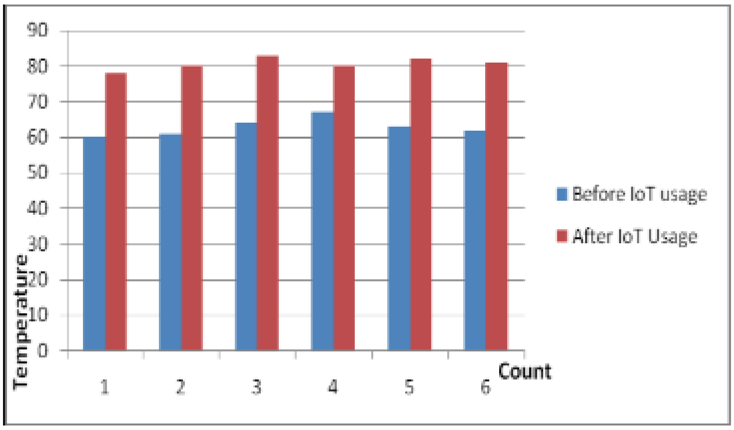


Figure 2.19: Temperature vs Number of patients (beneficiary) (Elankavi et al., 2022)

Overall, the IoT-based health monitoring system introduced by Elankavi et al. (2022) presents a thorough approach to real-time healthcare monitoring. By tackling issues such as reliance on internet connectivity and the intricacies of the system, this initiative highlights the considerable promise of IoT technologies in enhancing patient care and healthcare administration.

2.3.7 Low Cost IoT Sensor System for Real-time Remote Monitoring (D'Aloia et al., 2020; Khan et al., 2019)

The paper of "Low-Cost IoT Sensor System for Real-Time Remote Monitoring" authored by D'Aloia et al. (2020) and Khan et al. (2019) presents an economical Internet of Things (IoT) solution designed for real-time monitoring in various fields, including agriculture, environmental assessment, and smart city initiatives. This system utilizes affordable hardware components, such as microcontrollers (ESP32 or Arduino) and various sensors, to gather data on parameters like temperature, humidity, and air quality. The collected data is then sent to cloud platforms, including ThingsBoard and InfluxDB/Grafana, for purposes of visualization, storage, and trend analysis.

Figure 2.20: Device proposed (D'Aloia et al., 2020)

The architecture of the system integrates affordable microcontrollers along with a range of sensors designed to assess various parameters, including temperature, humidity, and air quality. The data gathered by these sensors is transmitted to cloud platforms for both storage and real-time visualization, enabling users to remotely observe environmental conditions. Additionally, the system features an interface that facilitates user interaction and data analysis.

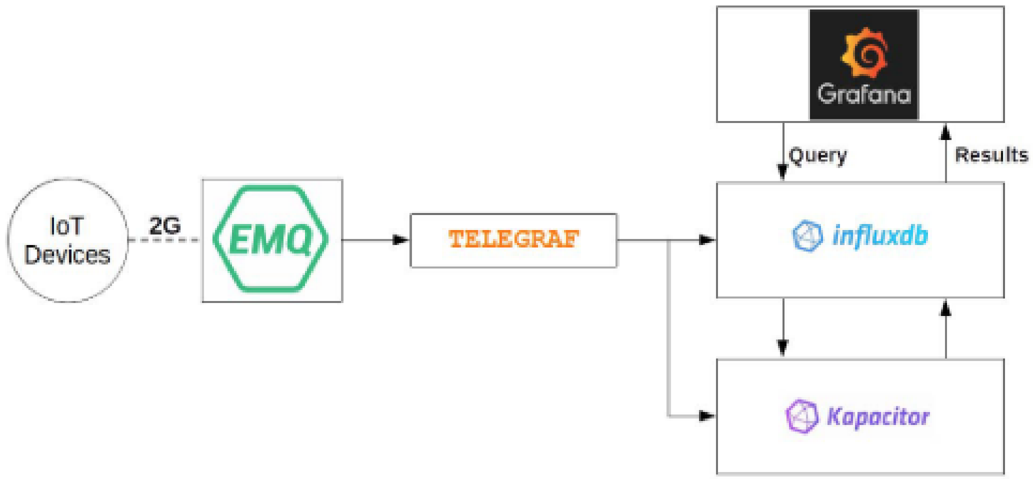


Figure 2.21: Architecture (D'Aloia et al., 2020)

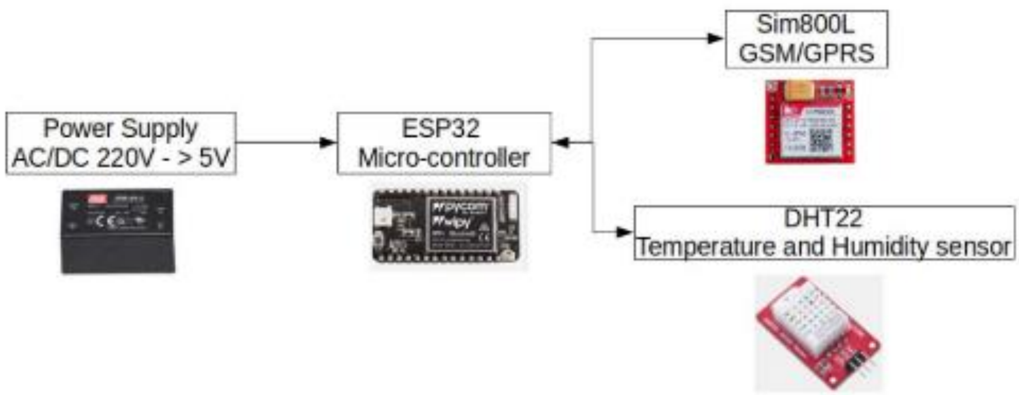


Figure 2.22:Scheme of the device (D'Aloia et al., 2020)

The project focuses on being affordable and easy to set up as its main advantages. It uses inexpensive hardware to make IoT technology for environmental monitoring available to more people the detail of the device is shown in Figure 2.23. Plus, the simple interface helps everyone understand the data, even those without technical skills. But the limitation is using cheap parts might impact how accurate the sensors are and how long they last, which could make them less suitable for tasks that need high precision. Also, the system relies on internet access for sending data (Figure 2.24 shows the interface of the data sent), which could limit its use in remote or less developed areas.

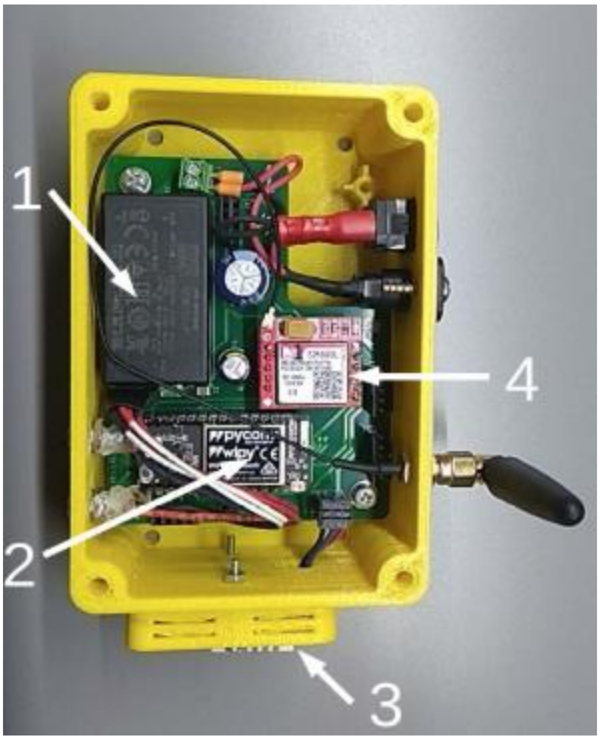


Figure 2.23: Detail of the device (D’Aloia et al., 2020)

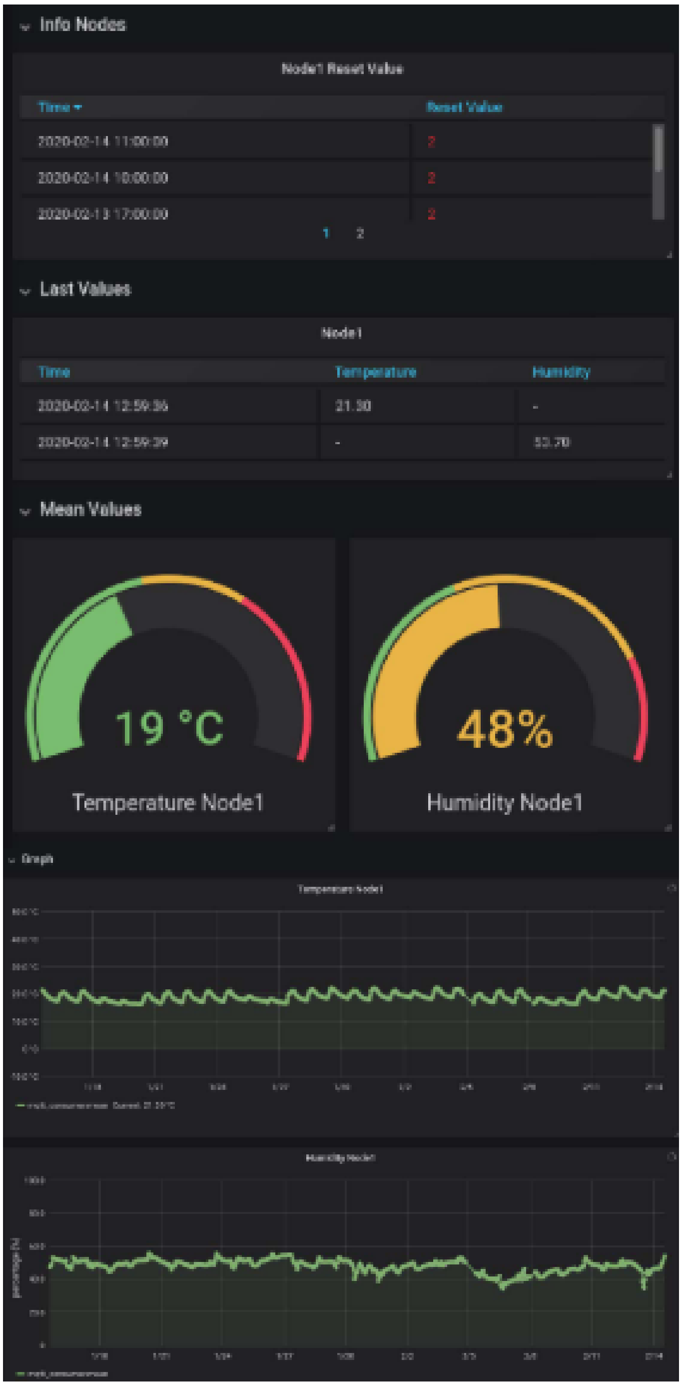


Figure 2.24: Interface (D'Aloia et al., 2020)

In summary, the paper shows that it is possible to create affordable IoT solutions for monitoring the environment in real-time. These solutions could be useful in areas like farming, smart cities, and managing disasters. It also highlights the importance of ongoing innovation to improve sensor accuracy and maintain reliable performance in different conditions.

2.3.8 IoT-based COVID-19 Suspect Smart Entrance Monitoring System (Roy et al., 2021)

In the paper entitled "IoT-Based COVID-19 Suspect Smart Entrance Monitoring System," Roy et al. (2021) showcase a smart system capable of monitoring people at building entrances as potential carriers of COVID-19. Such a system relies on IoT together with incorporated sensors and microcontrollers in checking body temperatures and oxygen saturation levels, automatically generating alerts on anomaly detection.

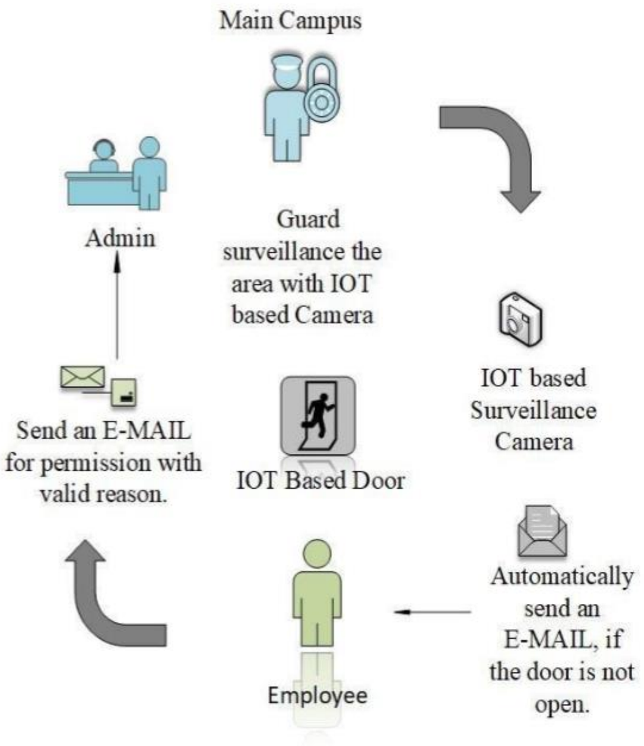


Figure 2.25: IoT-Based System (Roy et al., 2021)

The system uses an ESP32 microcontroller along with different sensors to collect real-time data, such as body temperature and SpO2 readings. The information is analysed through a tailored algorithm to categorize individuals as either normal or suspected cases. Email notifications are sent out to warn users if any unusual readings are found.

The project offers an automated, touchless solution for screening individuals, prioritizing safety and reducing human involvement. The incorporation of email alerts and data visualization improves system effectiveness and user-friendliness. However, the system depends significantly on the internet for data transfer, which may create difficulties in remote locations. Moreover, elements like environmental temperature and sensor precision can affect the dependability of measurements. Figure 2.26 shows the flowchart of the project, while figure 2.27 to figure 2.29 shows the output of the OLED and the alert notifications.

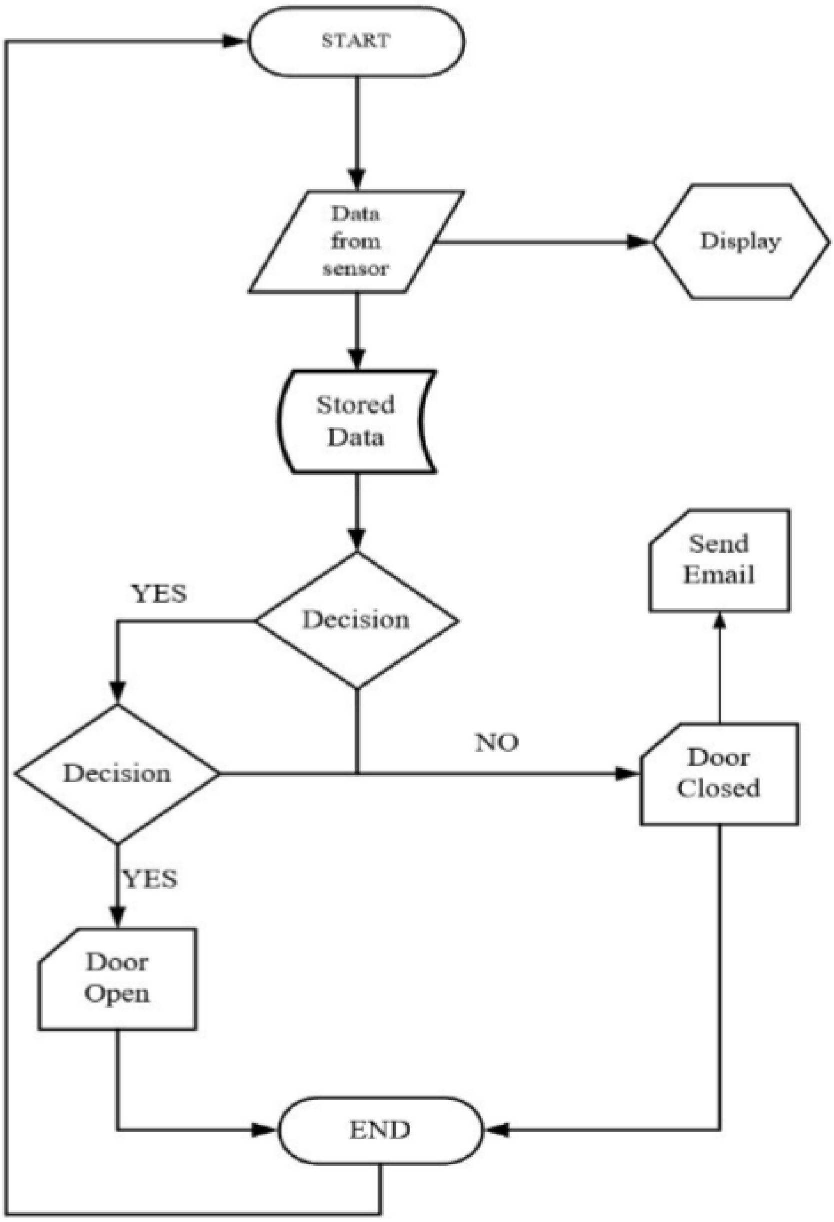


Figure 2.26: Flow Chart of the Algorithm (Roy et al., 2021)

Figure 2.27: Normal Result (Roy et al., 2021)

Figure 2.28: Suspected Result (Roy et al., 2021)

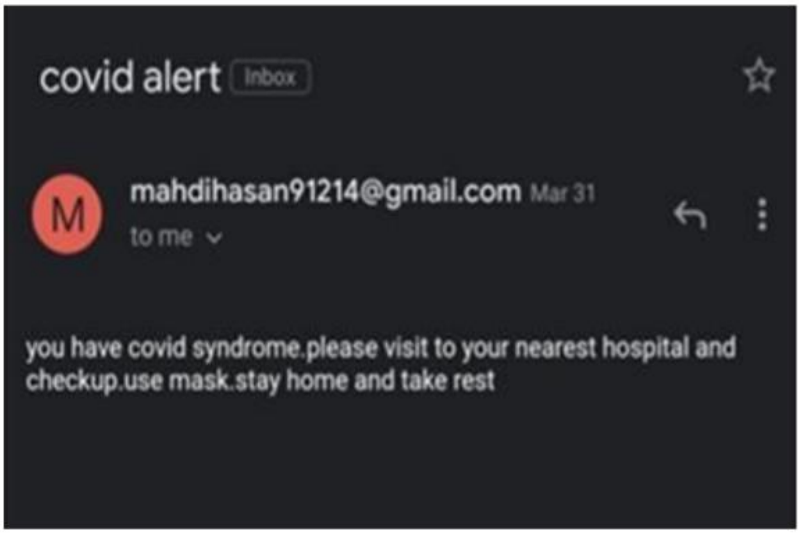


Figure 2.29: COVID-19 Suspect Email (Roy et al., 2021)

Figure 2.30 shows the graphical result of the project, the obtain through the sensor.

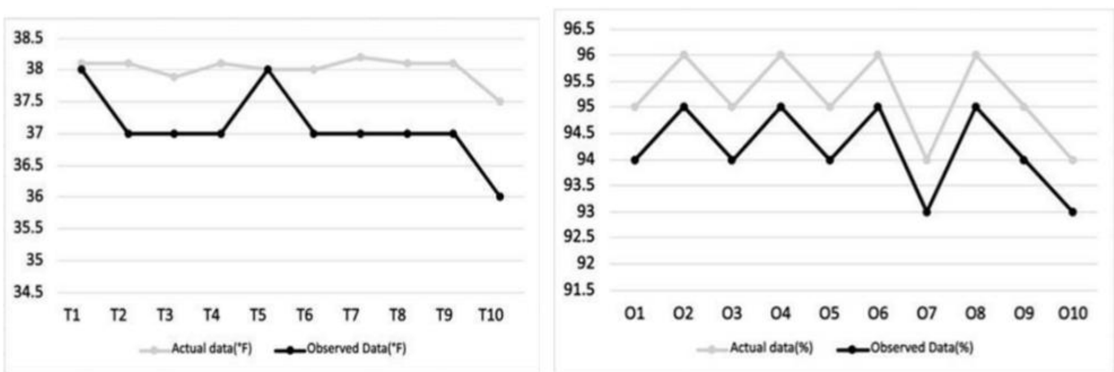


Figure 2.30: Graphical Interpretation of Body Temperatures and Oxygen Levels (Roy et al., 2021)

In summary, this study emphasizes the promise of IoT-based systems for health monitoring, especially in the fight against COVID-19. Nonetheless, advancements in sensor accuracy and offline functionality could further improve its use in various situations.

2.4 Summary of previous project

Previous Project	Summary	Advantage	Limitation
Remote Temperature Monitoring Using MQTT for IoT Smart Homes (Quamara et al., 2019)	This project focuses on using MQTT for low-latency real-time temperature monitoring, paired with a web-based dashboard for control and visualization.	Provides low latency and real-time notifications; integrates seamlessly with smart home systems.	Scalability issues for larger networks; depends on stable internet connectivity.
IoT-Based Temperature Monitoring System (Gada et al., 2021b)	This project focuses on remote temperature monitoring using IoT, with an emphasis on data acquisition and visualization through dashboards.	Provides reliable data collection and real-time visualization for monitoring temperature trends.	Lacks built-in alert features, making it less suitable for critical applications requiring immediate responses.
A ThingSpeak IoT on Real-Time Room Condition Monitoring System(Razali et al., 2020)	Uses ThingSpeak for monitoring and visualizing real-time room conditions, designed mainly for indoor environments.	Integrates seamlessly with ThingSpeak; energy-efficient sensors; supports real-time tracking.	Not suitable for outdoor or industrial settings; lacks focus on optimizing power usage.
Internet-of-Things Based Smart Temperature Monitoring System (Rao & Prema, 2018)	Monitors temperature and humidity with dashboards and notification features, targeting agriculture and smart homes.	Customizable alerts; energy-efficient design; intuitive dashboards for ease of use.	Needs reliable internet access; scalability is limited in larger networks.

An IoT-Based Real-Time Weather Monitoring System Using Telegram Bot and Thingsboard (Bestari & Wibowo, 2023)	Combines Telegram bots for real-time alerts with Thingsboard for visualizations, facilitating remote monitoring.	Convenient for Telegram users; strong alert system; benefits from Thingsboard analytics.	Relies on multiple platforms, which increases complexity; HTTP protocol is less efficient than MQTT.
Smart IoT-Based Human Well-being Monitoring in Healthcare System (Elankavi et al., 2022)	Introduces a system based on IoT that combines ESP32 and sensors to track human health, emphasizing temperature, heart rate, and environmental information.	Real-time observation of vital signs and environmental factors; facilitates multi-sensor integration for thorough health assessment.	Dependence on stable internet connectivity for data updates; sensor precision may be constrained by the use of cost-effective, lower-accuracy sensors.
Low Cost IoT Sensor System for Real-Time Remote Monitoring (D'Aloia et al., 2020)	Proposes an economical IoT system for monitoring temperature remotely, employing microcontrollers and cloud platforms for data storage and trend analysis.	Cost-efficient and expandable; utilizes platforms such as InfluxDB and Grafana for effective data visualization and trend assessment.	Limited to fundamental monitoring without sophisticated alert systems or decision-making functions.
IoT-Based COVID-19 Suspect Smart Entrance Monitoring System (Roy et al., 2021)	Explores a temperature monitoring system powered by IoT using ESP32 for assessing individuals based on body temperature and oxygen saturation, including automated alerts via email notifications.	Integrates real-time temperature monitoring with automated notifications for efficient and safe oversight in shared spaces.	- Relies significantly on internet stability for data transmission and alert notifications - External environmental factors may impact measurement precision.

2.5 Summary

The objective of this project is to address the limitations of existing IoT-based temperature monitoring systems while maximizing their benefits. Unlike the systems introduced by Quamara et al. (2019) and Bestari & Wibowo (2023), this study emphasizes scalability. Therefore, the proposed solution should be suitable for larger networks without sacrificing performance. Moreover, it prioritizes sensor precision to enhance data reliability, particularly in sensitive contexts. Taking significant input regarding customizable alarm features from Rao & Prema (2018), this project incorporates adaptable alert systems that are energy-efficient and suitable for long-term use.

Additionally, the project leverages insights from D'Aloia et al. (2020), which illustrate the effectiveness of integrating Grafana for data visualization with InfluxDB for database management. This strategy improves the system's capacity to analyze and present data effectively, offering users valuable insights. Such integration is in line with wider trends in IoT system development, which focus on user-friendly and scalable solutions.

The review points out deficiencies in current IoT-based temperature monitoring systems, such as limited scalability and inadequate emphasis on data accuracy in critical applications. This project seeks to resolve these challenges, enhancing IoT temperature monitoring with a robust, energy-efficient, and scalable solution that fills existing knowledge gaps.

CHAPTER 3 : METHODOLOGY

3.1 Introduction

This chapter gives the detail explanations of the proposed design and operational framework of the IoT-Based Wireless Thermometer for Remote Temperature Monitoring. The detail component or devices that used in the project are explained. Flowchart and block diagrams are included in this chapter for a clearer picture about the design of the system and how the operational framework.

3.2 System Design

This section provides a thorough evaluation of the device design, outlining all hardware and software components, their connections, and the overall functioning structure of the IoT-based wireless thermometer.

3.2.1 Hardware Component

3.2.1.1 ESP32

The ESP32 is the major processing unit that contains built-in Wi-Fi and Bluetooth for this project. It allows collecting, processing, and sending data in such a manner that communication and control within the system is guaranteed to be effective. The ESP32 is an excellent device in applications that require wireless connectivity with real-time processing.

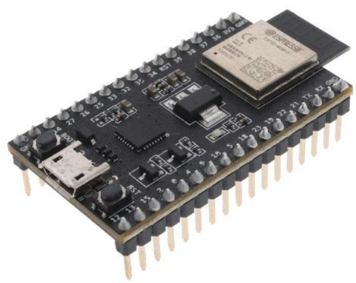


Figure 3.1: ESP32-DEVKIT

3.2.1.2 SHTC3 sensor

Figure 3.2 shows the SHTC3, which is a digital sensor specifically designed to deliver precise measurements of both temperature and humidity. This sensor is highly recognized for its ability to provide consistent and accurate data under changing environmental conditions. Moreover, it is designed to work with low power consumption, which makes it one of the best choices in applications that require efficiency in energy consumption. Its reliability and efficiency make it very suitable for continuous environmental monitoring within all kinds of settings.

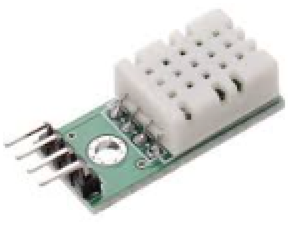


Figure 3.2: SHTC3 High Precision Temperature Humidity Sensor

3.2.1.3 TP 4050

Figure 3.3 shows the TP4056 module, which is a linear lithium-ion battery charger circuit. By combining a linear charger with constant voltage and constant current with thermal management, it offers a comprehensive charging solution. The micro-USB connector is usually used to supply a 5V input to the module, which then uses it to charge the battery to a steady 4.2V. The built-in protection features of the TP4056, which guarantee battery longevity and safety through overcharge, over discharge, and short-circuit protection, are among its primary characteristics. To make the module more user-friendly, it also has progress indicator LEDs that display the charging status.

Figure 3.3: TP4050

3.2.1.4 Lithium Battery

Lithium polymer batteries, or LiPo batteries for short, are a kind of rechargeable battery that has gained popularity in a variety of electronic applications because of its flexible form factor, high energy density, and lightweight design. LiPo batteries employ a polymer electrolyte instead of the liquid electrolyte used in conventional lithium-ion batteries, which enables a greater variety of shapes and sizes. They are perfect for use in small and portable devices because of their versatility. LiPo batteries are renowned for their ability to deliver high discharge rates, which is essential for applications that need sudden power increases. They also provide steady performance and a relatively lengthy lifespan. However, because incorrect use can result in swelling, overheating, or even fire, they must be handled and charged carefully.

Figure 3.4: LiPo Battery (3.7V)

3.2.1.5 XL6019

Figure 3.5 shows the XL6019, which is a voltage regulator that regulate voltages through DC-DC buck-boost converter. It provides a constant and regulated supply to the ESP32 microcontroller and other peripherals connected to it, irrespective of the fluctuation in the input voltage. It efficiently steps up or steps down the voltage depending on the requirement, which makes it very important in maintaining reliable operation and protection for sensitive components in the circuit.

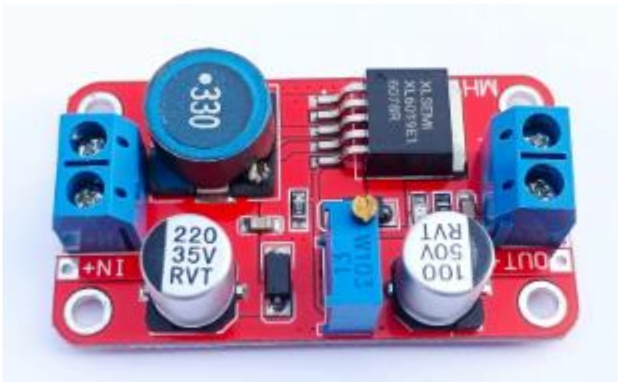


Figure 3.5: XL6019

3.2.2 Software Components

3.2.2.1 ThingSpeak

Thing Speak is a platform from Math Works that allows data from sensors to be collected, analyzed, visualized and acted on through modules such as Arduino, Raspberry Pi, Beagle Bone Black and so on. This platform mainly serves as a bridge that connects edge node devices such as sensors for analysis purposes. Th channel is the main element of the Thing Speak activity which contains data fields, location fields and also a status field. Data can be written to be created channel then processed and viewed by utilizing Mat lab coding. (IoT Analytics - ThingSpeak Internet of Things, n.d.)

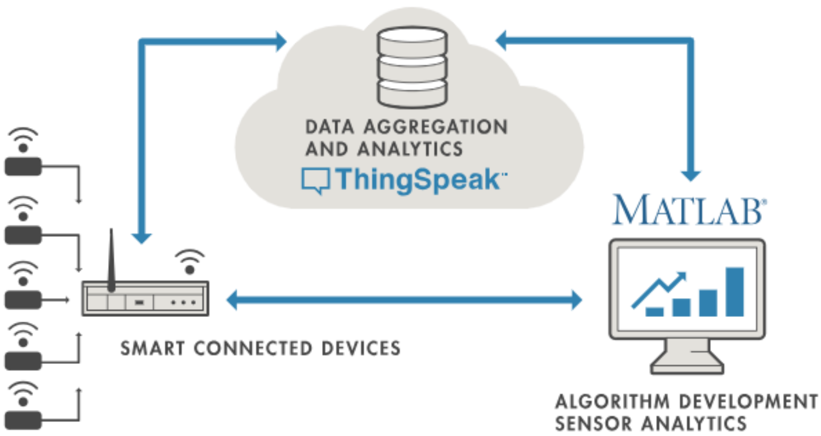


Figure 3.6: ThingSpeak (IoT Analytics - ThingSpeak Internet of Things, n.d.)

3.2.2.2 Google Sheets

Google Sheets is a cloud-based service that serves as a database for recording, saving, and overseeing temperature data gathered from sensors. It supports smooth integration with devices such as the ESP32 via web APIs, facilitating effective data transfer and access. The service offers an intuitive interface for structuring and displaying data, making it simple to share and analyze collaboratively. Its capabilities include real-time updates and compatibility with different tools, aiding in sophisticated data processing and visualization for oversight and decision-making tasks.

Figure 3.7: Google Sheets

3.2.2.3 Telegram Bot

Telegram Bot serves as a medium to deliver real-time alerts and notifications to users when set temperature limits are surpassed. This integration improves the system's responsiveness by promptly informing users of critical situations, allowing for swift action. The bot promotes user interaction through instant messaging, ensuring that updates are received without delay. It offers a dependable and effective communication channel, positioning it as a vital element for sustaining awareness and control within the system. (*Telegram Bot API*, n.d.)

Figure 3.8: Telegram Bot

3.2.3 Circuit diagram & Schematic diagram

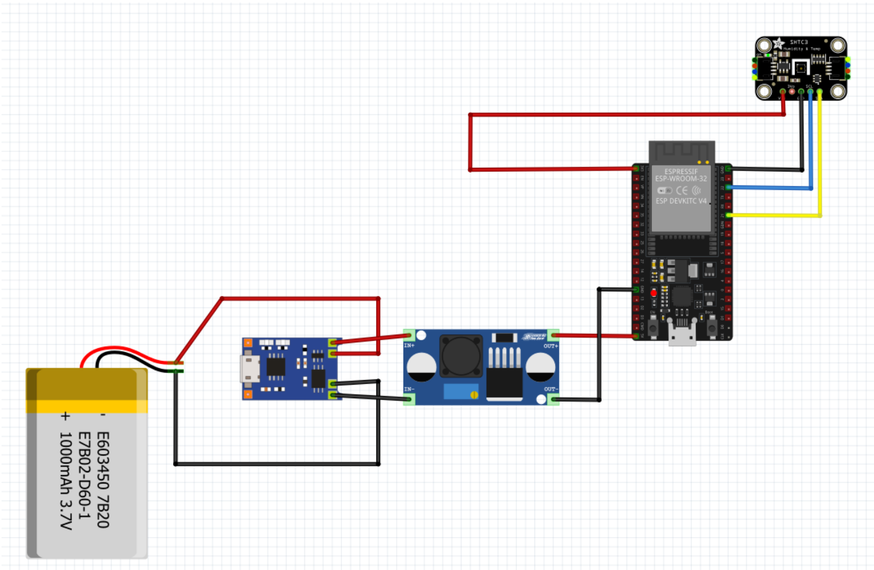


Figure 3.9: Circuit Diagram for the connection of the hardware components

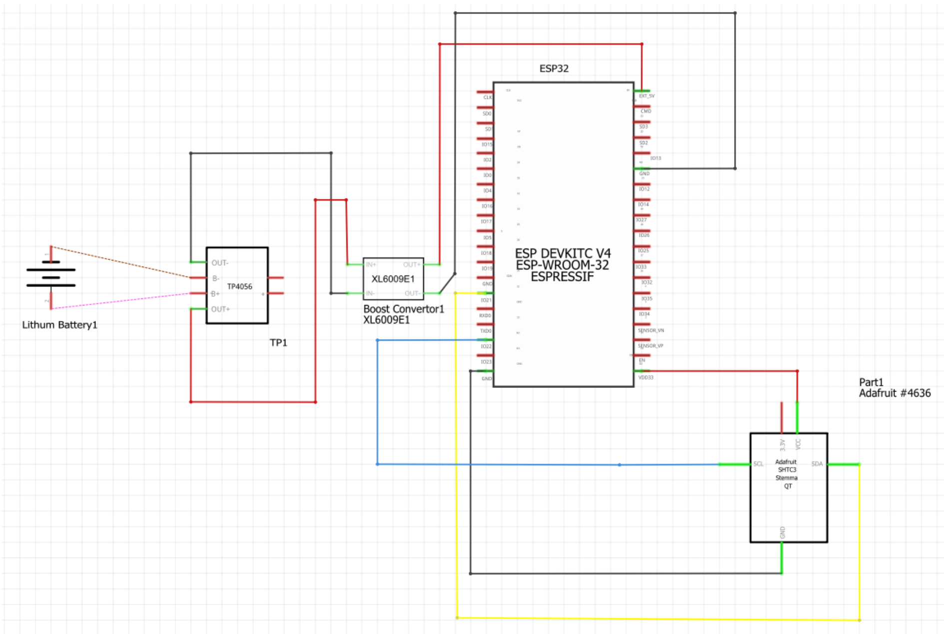


Figure 3.10: Schematic Diagram of the connection of hardware components

3.2.4 Block Diagram

The IoT-Based Wireless Thermometer for Remote Temperature Monitoring system combines hardware and software elements to enable effective environmental data collection, processing, storage, and communication. The power supply module features a 3. 7V LiPo battery, which acts as the main energy source, being compact, rechargeable, and suitable for portable uses. To ensure safe charging routines and prolonged battery life, the TP4056 charger module is utilized, providing protection against overcharging and over-discharging. Furthermore, the XL6019 DC-DC converter stabilizes the battery's output, ensuring a steady voltage supply to power the ESP32 microcontroller and other connected devices, guaranteeing system stability and efficiency.

The sensor node consists of the ESP32 microcontroller and the SHTC3 sensor. The ESP32 acts as the main processing unit, harnessing its built-in Wi-Fi and Bluetooth features to handle data collection, processing, and wireless communication. It gathers accurate environmental temperature and humidity data from the SHTC3 digital sensor, processes this data, and transmits it to cloud services. The SHTC3 sensor is recognized for its precision and low power use, making it suitable for continuous environmental monitoring.

For cloud services integration, the system employs various platforms to improve functionality and user engagement. ThingSpeak is used for collecting, analyzing, and displaying sensor data, allowing for real-time monitoring and historical trend analysis. Google Sheets functions as a cloud-based spreadsheet app for recording sensor data, offering an easy-to-use interface for data storage, sharing, and further analysis. In addition, the system integrates a Telegram Bot to send real-time alerts and notifications when temperature readings surpass set thresholds. This feature increases user involvement by ensuring prompt awareness and response to critical conditions.

Together, these components form a strong and efficient system for remote temperature monitoring, providing a seamless blend of data acquisition, processing, visualization, and user engagement.

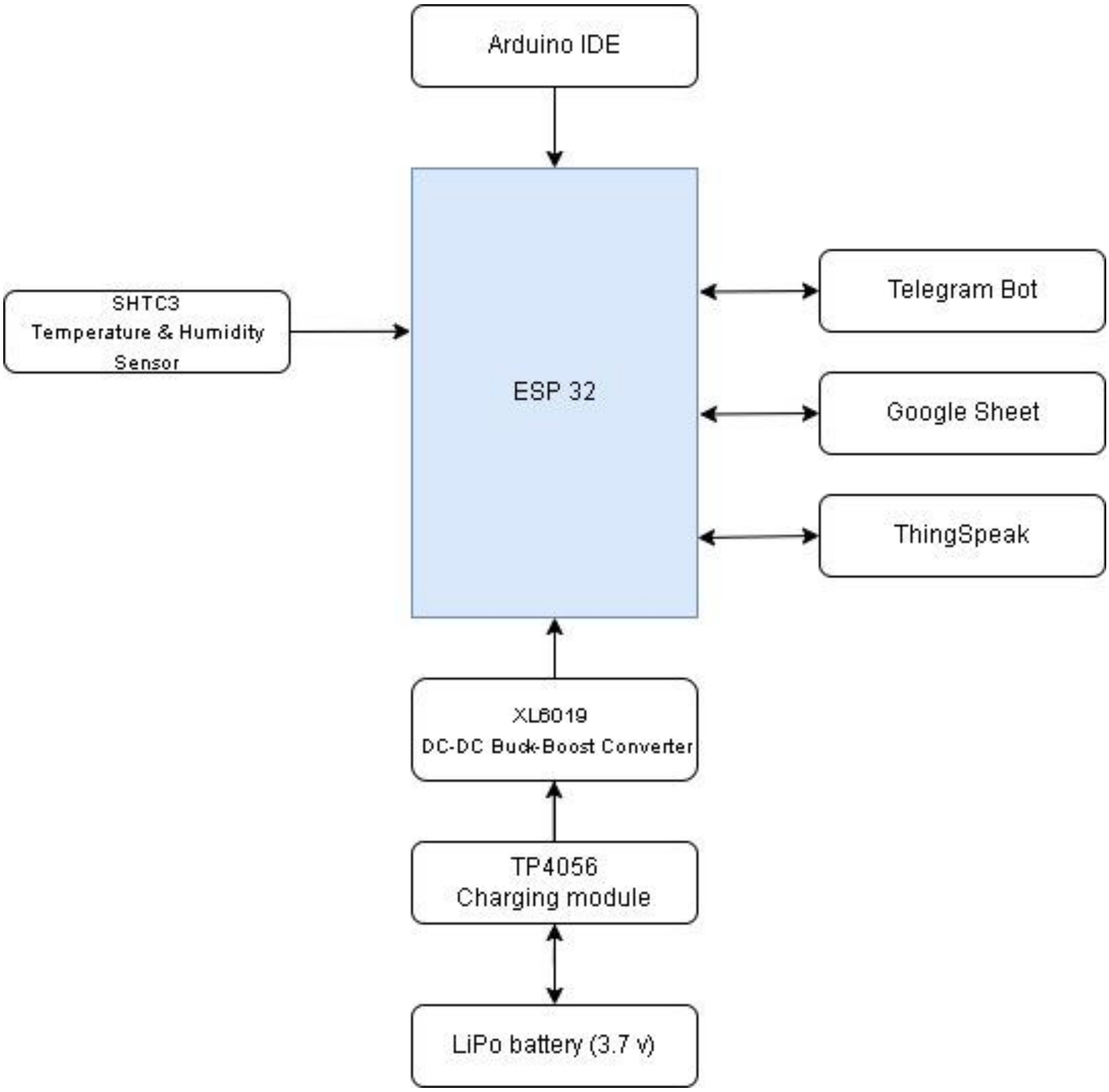


Figure 3.11: Block Diagram of the IoT based Thermometer

3.2.5 Flowchart

The flowchart presents a comprehensive overview of the operational framework for the IoT-Based Wireless Thermometer for Remote Temperature Monitoring system using Microcontroller, illustrating its methodical approach to data collection, processing, and communication. The process starts with the initialization of the ESP32 microcontroller, serving as the central hub, along with the SHTC3 temperature and humidity sensor. The ESP32, featuring built-in Wi-Fi and Bluetooth, gathers real-time environmental data from the sensor, selected for its high accuracy and energy efficiency.

The system verifies the sensor data to ensure accuracy before advancing to the data processing stage, where raw readings are formatted for cloud transmission. The processed data is subsequently transmitted to platforms such as ThingSpeak and Google Sheets, with ThingSpeak offering real-time visualization and analysis, while Google Sheets delivers a user-friendly interface for data logging and sharing. This integration underscores the system's adaptability and versatility.

A crucial feature includes monitoring temperature data against a predetermined threshold. If this threshold is surpassed, the system utilizes the Telegram Bot to send prompt alerts to users, facilitating timely responses. In case of invalid data, error-handling mechanisms are in place to prevent interruptions in the monitoring process.

Finally, the system enters a waiting state prior to the next measurement cycle, ensuring ongoing and energy-efficient operation. This workflow demonstrates advanced knowledge of embedded systems, cloud integration, and IoT principles, merging technical expertise with strategic design to provide a dependable and scalable solution for remote temperature monitoring.

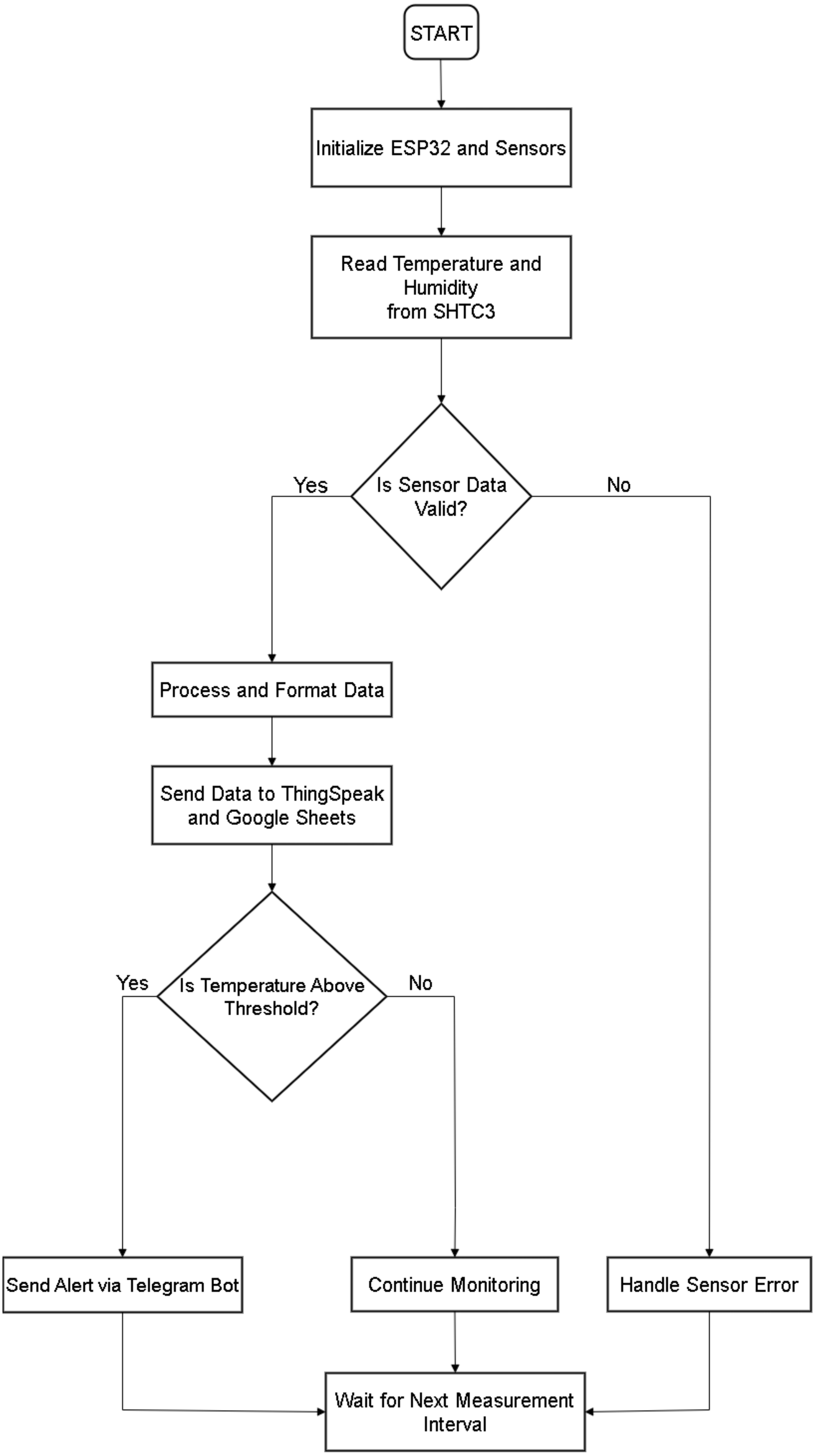


Figure 3.12: Flowchart of the IoT-based Thermometer

3.3 Testing and Validation

This section outlines the techniques used to assess the functionality and precision of the IoT-Based Wireless Thermometer system, including both simulated and real-world testing environments.

3.3.1 Simulation testing with Wowki

The Wokwi online simulation platform was used to verify the project's design and functionality. Wokwi provides a virtual space for prototyping and testing embedded systems, allowing developers to simulate hardware components and microcontrollers without needing physical devices.

In this simulation, the DHT22 sensor was used instead of the SHTC3 sensor to measure temperature and humidity. The DHT22 is a widely used digital sensor that can deliver basic temperature and humidity readings, making it appropriate for simulation. It is essential to understand that this substitution was made only for simulation; the project implementation uses the SHTC3 sensor.

The simulation required configuring the ESP32 microcontroller to connect with the DHT22 sensor, gathering environmental data, and sending it to cloud services like ThingSpeak and Google Sheets. Furthermore, the system was programmed to send notifications via a Telegram bot when certain thresholds were surpassed. This configuration enabled thorough testing of the system's data acquisition, processing, and communication capabilities within a controlled virtual environment.

By utilizing Wokwi's simulation features, the project's design was extensively validated, ensuring that the hardware and software components operated as expected before proceeding on to physical implementation.

Figure 3.13: Wokwi Simulation (Wokwi - World’s Most Advanced ESP32 Simulator, n.d.)

3.3.2 Integration and Real-world Testing

Figure 3.14 shows the Arduino code utilized to set up the ESP32 microcontroller for sensor integration and communication. Essential elements of the code involve the setup of Wi-Fi credentials, the Google Apps Script Web App URL, and the Telegram bot token, which facilitate smooth data transmission and notification services. The simulation carried out on the Wokwi platform, features a virtual circuit that includes the ESP32 microcontroller, a DHT22 sensor for measuring temperature and humidity, and an LED for visual indication. This simulation enabled comprehensive testing and confirmation of the system's functionality in a regulated virtual setting before moving on to physical implementation.

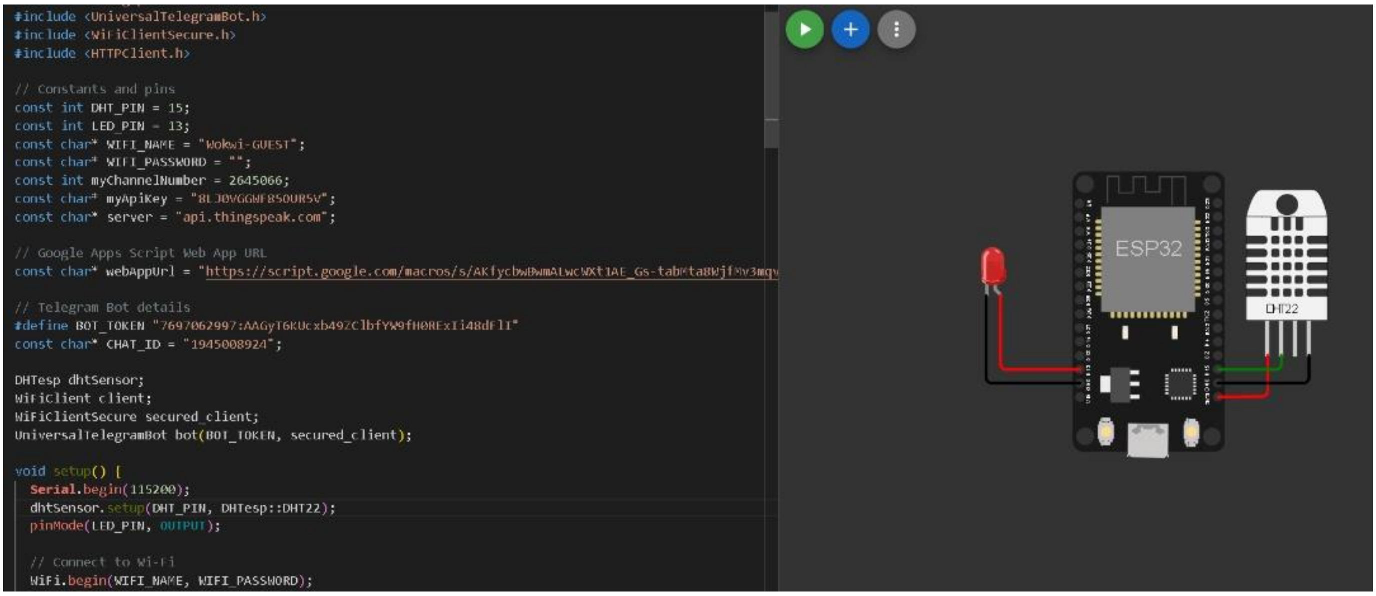


Figure 3.14: Code and Circuit Simulation (Esp32-Dht22-Thingspeak Copy (2) - Wokwi ESP32, STM32, Arduino Simulator, n.d.)

Figure 3.15 presents the ThingSpeak dashboard, highlighting the collected environmental data in different formats, such as line charts and gauges. The line charts give a visual depiction of temperature and humidity trends over time, allowing for easy monitoring of variations. Furthermore, the gauges provide real-time insight into the current temperature and humidity levels, supporting prompt oversight and evaluation of the system's data collection and transmission functionalities.

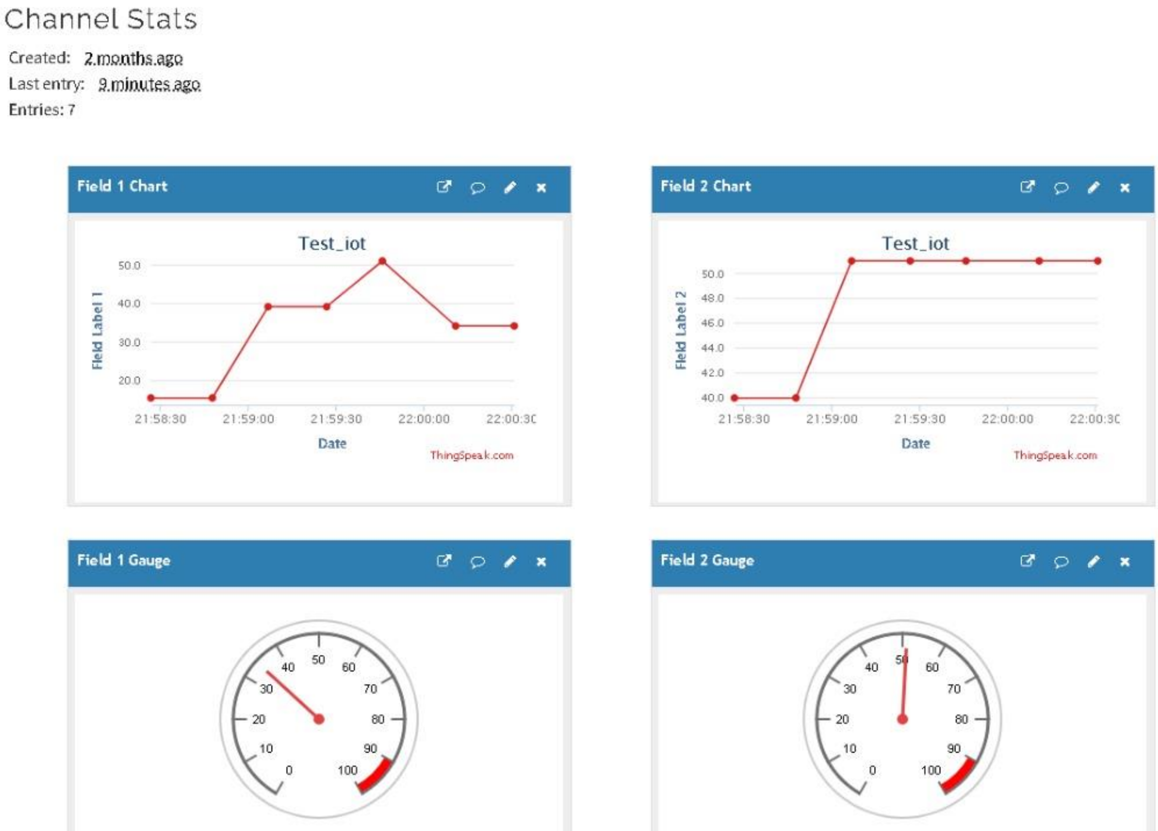
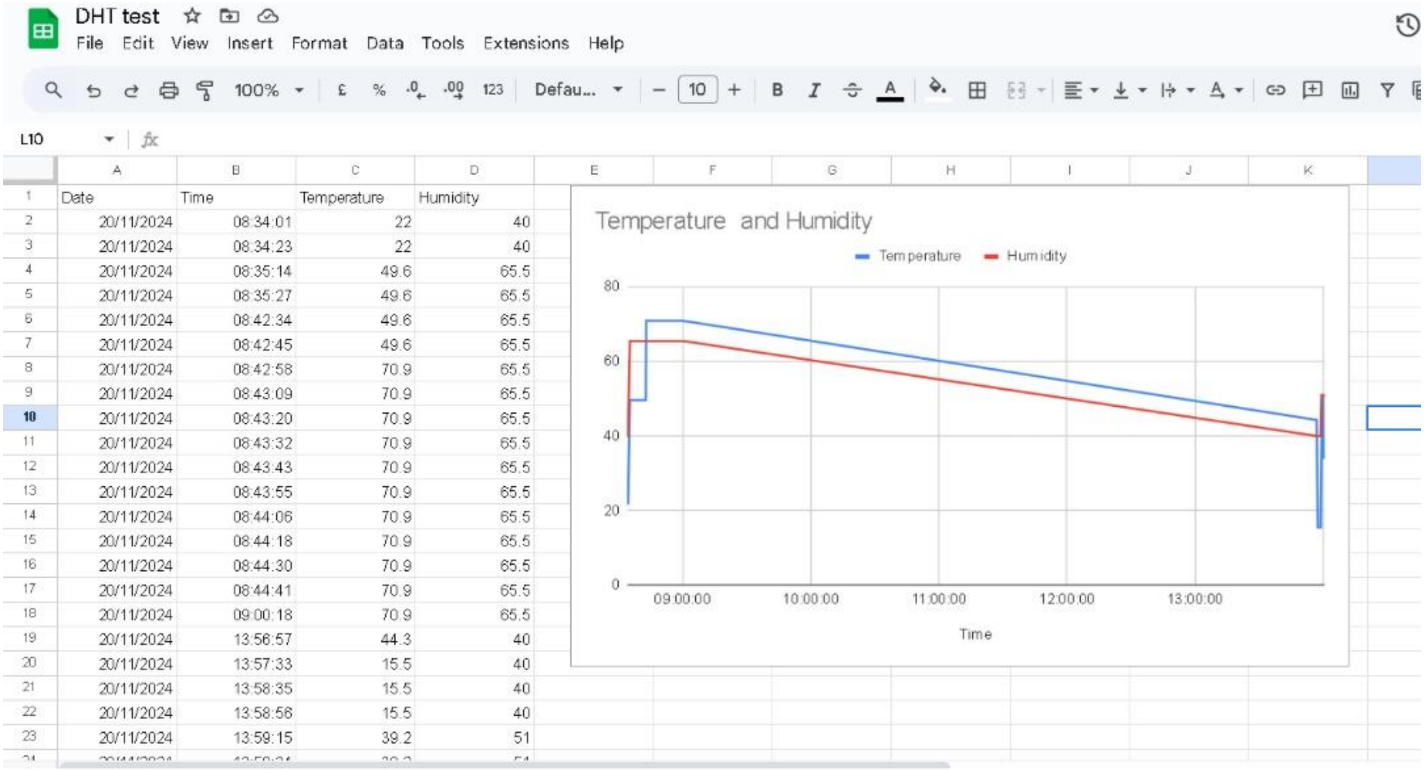


Figure 3.15: ThingSpeak Data Visualization (Test_iot - ThingSpeak IoT, n.d.)

The Figure 3.16 shows a Google Sheets spreadsheet that includes documented temperature and humidity data, accompanied by a graph illustrating trends over time. This clearly showcases the system's ability to record environmental data in Google Sheets, facilitating further analysis, documentation, and convenient access for users.



Date	Time	Temperature	Humidity
20/11/2024	08:34:01	22	40
20/11/2024	08:34:23	22	40
20/11/2024	08:35:14	49.6	65.5
20/11/2024	08:35:27	49.6	65.5
20/11/2024	08:42:34	49.6	65.5
20/11/2024	08:42:45	49.6	65.5
20/11/2024	08:42:58	70.9	65.5
20/11/2024	08:43:09	70.9	65.5
20/11/2024	08:43:20	70.9	65.5
20/11/2024	08:43:32	70.9	65.5
20/11/2024	08:43:43	70.9	65.5
20/11/2024	08:43:55	70.9	65.5
20/11/2024	08:44:06	70.9	65.5
20/11/2024	08:44:18	70.9	65.5
20/11/2024	08:44:30	70.9	65.5
20/11/2024	08:44:41	70.9	65.5
20/11/2024	09:00:18	70.9	65.5
20/11/2024	13:56:57	44.3	40
20/11/2024	13:57:33	15.5	40
20/11/2024	13:58:35	15.5	40
20/11/2024	13:58:56	15.5	40
20/11/2024	13:59:15	39.2	51

Figure 3.16: Google Sheets Data Logging (DHT Test - Google Sheets, n.d.)

The Figure 3.17 shows a screenshot of the Telegram bot sending notifications to the user when temperature readings (in this case, it is more than 40 degree) go beyond a specified limit. Each notification message includes a warning icon alongside the exact temperature value recorded, emphasizing the system's real-time alert capability and its efficiency in informing users quickly about urgent situations.

Figure 3.17: Telegram Notifications

CHAPTER 4 : RESULTS & DISCUSSION

4.1 Introduction

CHAPTER 5 : CONCLUSION

5.1 Introduction

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APPENDIX A

Table 5.1: Gantt Chart

TASK	MILESTONES	PROGRESS	START	END
Initiation				
Create a Preliminary Project Scope		100%	10/14/24	10/14/24
Analyze Existing Solutions		100%	10/14/24	10/20/24
Conduct Literature Review on IoT thermometer		100%	10/20/24	11/3/24
Project Planning and Design				
Define Hardware and Software Requirements	No	100%	11/3/24	11/17/24

Select platform IoT and Database	No	100%	11/5/24	11/19/24
Develop System Design	No	100%	11/19/24	12/21/24
Plan for Prototype Development (for FYP2)	No	60%	12/21/24	1/10/25
Execution				
Project Simulation	Simulation of IoT thermometer completed successfully	50%	1/11/25	1/25/25
Iterative System Testing	System tested and issues resolved	10%	1/26/25	2/5/25
Develop Future Work Plan (for FYP2)	Plan for prototype development finalized	0%	2/6/25	2/15/25
Evaluation				
Monitor progress	No	0%	2/16/25	2/20/25
Evaluate progress	No	0%	2/21/25	2/25/25

Table 5.2: Progress Week 1 - Week 4

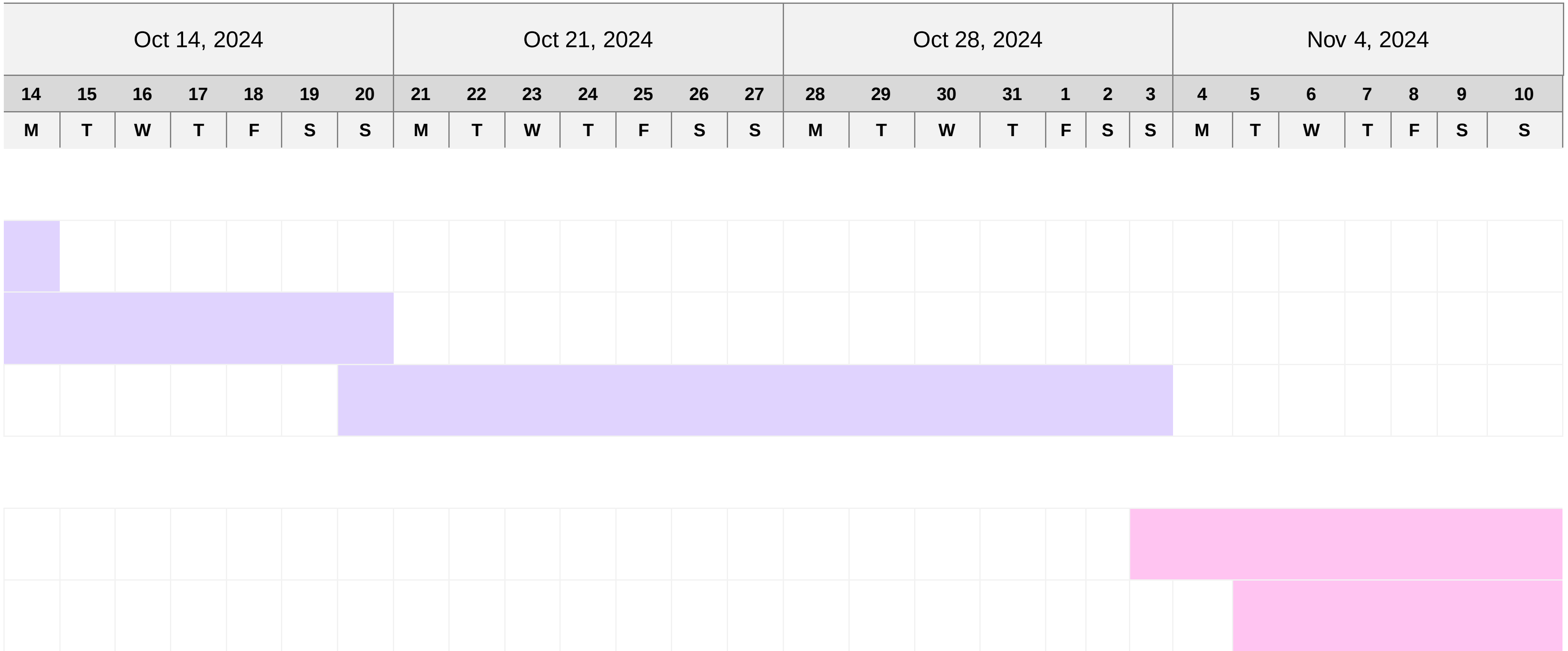

Table 5.3: Progress Week 5 - Week 8

Nov 11, 2024							Nov 18, 2024							Nov 25, 2024							Dec 2, 2024						
11	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
M	**T**	**W**	**T**	**F**	**S**	**S**	**M**	**T**	**W**	**T**	**F**	**S**	**S**	**M**	**T**	**W**	**T**	**F**	**S**	**S**	**M**	**T**	**W**	**T**	**F**	**S**	**S**

Table 5.4: Progress Week 9 - Week 12

Dec 9, 2024							Dec 16, 2024							Dec 23, 2024							Dec 30, 2024						
9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	1	2	3	4	5
M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S

Table 5.5: Progress Week 13 - Week 16

Jan 6, 2025							Jan 13, 2025							Jan 20, 2025							Jan 27, 2025						
6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	1	2
M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S

Table 5.6: Progress Week 17 - Week 20

Jan 27, 2025							Feb 3, 2025							Feb 10, 2025							Feb 17, 2025						
27	28	29	30	31	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S

APPENDIX B

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Figure 5.1: Turnitin Chapter 1

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Figure 5.2: Turnitin Chapter 2

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