Project report

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A full analysis of the project is provided in the IoT_Environmental_Monitoring_System_report.pdf file.

I. Introduction

The Internet of Things (IoT) is a rapidly growing field of technology that integrates devices and sensors into a shared communication network, enabling real-time data collection and analysis. This project focuses on the creation of a functional IoT node, leveraging cutting-edge technologies such as the ESP32 microcontroller, the DHT11 sensor, and the Thinger.io platform. The project emphasizes the ability to collect, visualize, and analyze environmental data, as well as to remotely control devices via the Internet.

The approach taken combines hardware and software development to build a smart system. The ESP32, a powerful and versatile microcontroller, allows for efficient data processing and Internet connectivity. The DHT11 sensor is used to measure temperature and humidity, while the LCD screen is employed for local data display. Additionally, the Thinger.io platform enables data storage, analysis, and remote presentation through a dynamic dashboard. The system also offers remote control capabilities of an LED device, showcasing the power of IoT applications in management and automation.

The project is based on well-established technologies and libraries, such as the DHT sensor library and LiquidCrystal I2C, ensuring smooth communication between devices. The choice of the Thinger.io platform was driven by its ease of use and scalability, making it ideal for implementing IoT applications at small or large scale. Furthermore, the literature consulted provided a theoretical foundation for understanding IoT technologies and supported the practical implementation of the system.

The project deliverable includes a complete IoT system, combining data collection, both local and remote visualization, and remote control functionality. The report is structured in distinct sections, covering the introduction to IoT, analysis of the project's relationship to the technology, the implementation process, and the conclusions derived from the study. Through this project, the capabilities and practical value of IoT are highlighted, demonstrating its accessibility and functionality for both everyday and more specialized use cases.

II. Relationship to IoT

The Internet of Things (IoT) refers to the collective network of interconnected devices and the technology that facilitates communication between devices, the cloud, and one another. Advances in low-cost microprocessors and high-speed communication have enabled everyday objects such as toothbrushes, vacuum cleaners, cars, and machines to connect to the Internet. These devices collect data through sensors and respond intelligently to user actions.

A typical IoT system functions by collecting and exchanging data in real time. It involves three main components: smart devices, an IoT application, and a user interface. Smart devices, such as TVs or cameras, have computing capabilities, collect data from the environment or user, and communicate with the IoT application via the Internet. The IoT application analyzes the data using technologies such as Artificial Intelligence (AI) or Machine Learning (ML), and makes decisions that are sent back to the devices, enabling intelligent responses. Finally, the user interface, such as an app or website, allows the user to manage the devices.

In the context of this project, IoT capabilities are utilized to create a node that collects and records environmental data, such as temperature and humidity, using a DHT11 sensor. The system connects to the Internet via the ESP32 microcontroller, which handles data collection and processing. The data is displayed locally on an LCD screen and sent to the Thinger.io platform for remote storage, monitoring, and analysis. Additionally, the system enables remote control through the Thinger.io dashboard, allowing for the control of an LED device from a distance.

The goal of the project is to develop a functional and reliable IoT node that collects real-time temperature and humidity data, displays it locally via the LCD screen, stores and analyzes it remotely through the Thinger.io platform, and provides remote control capabilities via the dashboard. The project aims to demonstrate the flexibility and usefulness of IoT in data collection and remote device control.

The developed system can be applied in various real-world scenarios. In smart homes, it can monitor temperature and humidity in spaces such as bedrooms, living rooms, or storage areas, while the remote LED control can be adapted for managing lighting or other devices. In agriculture, the system can monitor temperature and humidity conditions in greenhouses, contributing to optimizing crop growth. In industry, it can be used in storage facilities to monitor critical temperature and humidity conditions, with the ability to send alerts in case of anomalies. Finally, in smart cities, the system can be part of a larger IoT network for monitoring environmental conditions such as temperature and humidity in public spaces.

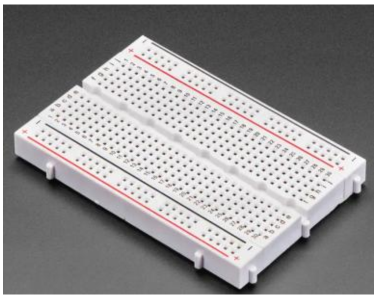
This project demonstrates how IoT technologies can be integrated into everyday life, enabling data collection, remote monitoring, and device control, with the goal of increasing efficiency and convenience.

III. Project Description

Materials and Tools

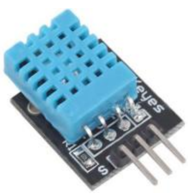
The following materials were used for building the system:

- **Breadboard**: Used for assembling electronic components.



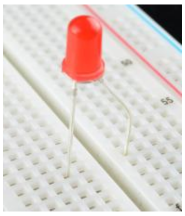
- **ESP32**: Acts as the microcontroller responsible for data processing and communication. The ESP32-C3 WROOM used in this project is a RISC-V-based microcontroller with a single-core CPU up to 160 MHz, 400 KB SRAM, and external flash memory support. It supports Wi-Fi (802.11 b/g/n) and Bluetooth 5 (BLE) and includes security features such as data encryption and secure boot. It is widely used in smart home and industrial applications and allows easy interfacing with external devices via GPIO pins. In this project, the ESP32 collects data from sensors and communicates with the Thinger.io platform to enable remote control and data analysis.

- **DHT11**: The DHT11 sensor measures environmental temperature and humidity using an NTC thermistor and a capacitive humidity sensor. It has four pins (VCC, GND, Data, and NC) and uses a single-wire communication protocol. The Adafruit DHT sensor library simplifies its use. In this project, the DHT11 records temperature and humidity data which are processed by the ESP32 and sent to Thinger.io.

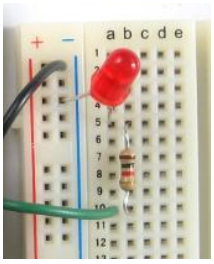


- **LCD Screen (I2C)**: LCDs use liquid crystals between polarizers and electrodes to display information. They are backlit and commonly used in monitors, phones, and clocks. The LCD in this project displays real-time temperature and humidity readings.

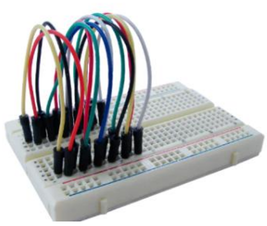
- **LED Light**: Used as an indicator for system operation.



- **Resistor**: Used to protect the circuit.



- **Connecting Wires**: For wiring the components together.



- **Thinger.io**: A cloud-based IoT platform used for managing connected devices. It enables data storage, analysis, and remote monitoring via dashboards. It supports uplink/downlink, automatic device provisioning, and data management. In this project, it is used for remote data storage and monitoring from the DHT11 sensor, as well as remote control of the LED device.

Implementation Steps

1. **Circuit Assembly**
   The circuit was built step-by-step on a breadboard. All components including the ESP32, DHT11 sensor, LCD screen, and LED were connected using jumper wires. The system was tested for proper operation.

2. **ESP32 Setup**
    - Necessary drivers were installed to ensure the ESP32 was recognized by the computer.
    - The ESP32 was connected via USB and the connection was verified.
3. **Library Installation and Initial Testing**
    - **DHT11 Sensor**: The Adafruit DHT sensor library was installed. The DHTtester example was used to verify proper sensor operation.
    - **LCD Screen**: The LiquidCrystal I2C library was installed. The CustomChars example was used to confirm functionality.

Code Functionality
The system performs four key tasks:

- It collects temperature and humidity data using the DHT11 sensor, processed in real-time by the ESP32.
- It displays these readings on the LCD screen using the LiquidCrystal I2C library, updated every second.
- It uses the Thinger.io library to send this data to the cloud via Wi-Fi, where it's stored in data buckets and displayed on a dashboard.
- It listens for remote commands from the Thinger.io dashboard to turn an LED on or off using callback functions, allowing real-time device interaction.

Thinger.io Integration

Platform Setup:

- Installed the Thinger.io library by Alvaro Luis (v2.25.1).
- Created a Thinger.io account and a new device for the ESP32 with unique credentials.

Functionality:

- The ESP32 connected to the internet and began transmitting temperature and humidity data to Thinger.io.
- Data was stored in buckets and displayed on the dashboard.

Dashboard Design:

- **Measurement Log Table**: Timestamped temperature and humidity readings.
- **Latest Values Panel**: Most recent temperature and humidity values.
- **Temperature Graph (24h)**: Hourly evolution.

- **Average Temperature (5 min)**: Calculated and sent from the microcontroller.
- **Humidity Graph (20 min)**: Humidity trend over 20 minutes.
- **LED Control Switch**:
    - Pressing ON sends a command to the ESP32 to turn the LED on.
    - Pressing OFF turns it off.

Switch Implementation
The ESP32 receives ON/OFF commands via Thinger.io and updates the LED status instantly, with visual confirmation on the dashboard. Callback functions ensure accurate and real-time switching behavior.

IV. Conclusion

The implementation of the IoT system developed in this project demonstrated the effectiveness and functionality of IoT technologies for collecting, storing, and managing environmental data. Using the ESP32 microcontroller, the DHT11 sensor for measuring temperature and humidity, and an LCD screen for local display, a reliable real-time system was created. Integration with Thinger.io allowed for cloud storage and remote visualization of the data through a custom dashboard, enhancing remote monitoring and analysis capabilities.

The system successfully incorporated key IoT principles, such as internet-connected devices and centralized data management. The remote control of an LED via the dashboard showcased the practical potential of IoT for automation and remote device management. The switch implementation further enhanced the system's interactivity and usability.

This project highlighted the flexibility and applicability of IoT technology in a wide range of real-world scenarios, such as smart homes, greenhouses, industrial storage environments, and public spaces. The results confirm that IoT systems can improve efficiency, accuracy, and convenience in everyday applications, paving the way for further automation and optimization.

Final results

Refresh

Last 24 hours

Date	temperature avg1h
11/12/2024, 11:19:02 μ.μ.	24.63472557067871
11/12/2024, 10:18:19 μ.μ.	null
11/12/2024, 9:10:08 μ.μ.	null
11/12/2024, 7:19:38 μ.μ.	null
11/12/2024, 6:19:02 μ.μ.	24.34744644165039
11/12/2024, 5:18:18 μ.μ.	24.0424747467041
11/12/2024, 4:17:34 μ.μ.	null
11/12/2024, 3:16:59 μ.μ.	24.406646728515625
11/12/2024, 2:16:15 μ.μ.	23.763601303100586
11/12/2024, 12:35:14 μ.μ.	24.27086639404297
11/12/2024, 10:58:20 π.μ.	24.981637954711914
11/12/2024, 9:57:36 π.μ.	24.427263259887695
11/12/2024, 8:56:53 π.μ.	23.34524154663086
11/12/2024, 7:56:09 π.μ.	23.523019790649414
11/12/2024, 6:55:26 π.μ.	23.423866271972656
11/12/2024, 5:54:42 π.μ.	23.3469181060791

Refresh

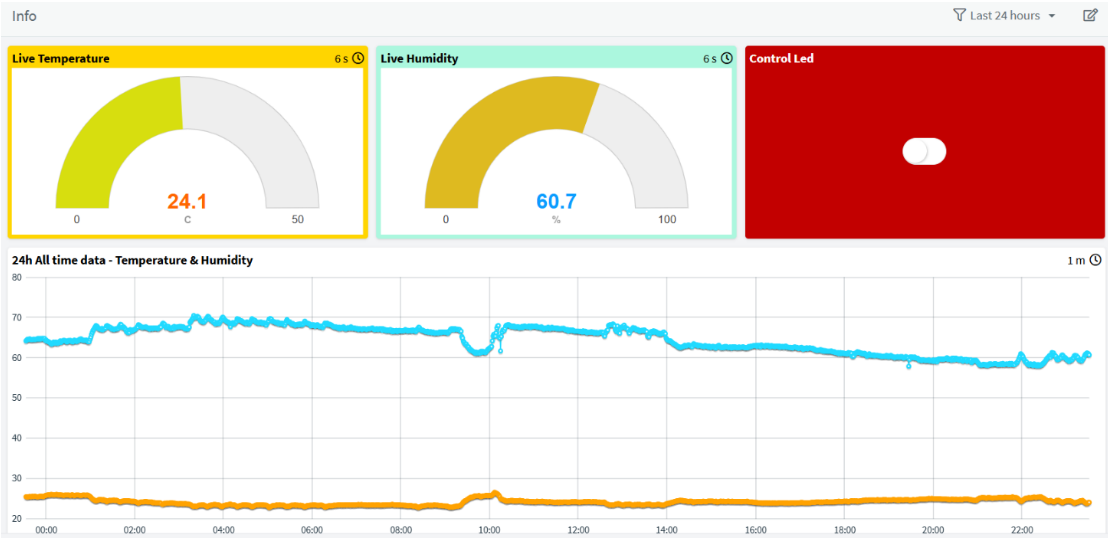
Last 24 hours

Date	humidity	temperature
11/12/2024, 11:40:21 μ.μ.	59.599998474121094	24.399999618530273
11/12/2024, 11:39:20 μ.μ.	59.5	24.399999618530273
11/12/2024, 11:38:20 μ.μ.	59.5	24.399999618530273
11/12/2024, 11:37:20 μ.μ.	59.70000076293945	24.399999618530273
11/12/2024, 11:36:19 μ.μ.	59.900001525878906	24.299999237060547
11/12/2024, 11:35:19 μ.μ.	59.900001525878906	24.399999618530273
11/12/2024, 11:34:20 μ.μ.	60.20000076293945	24.299999237060547
11/12/2024, 11:33:18 μ.μ.	60.20000076293945	24.299999237060547
11/12/2024, 11:32:17 μ.μ.	60.70000076293945	24.100000381469727
11/12/2024, 11:31:17 μ.μ.	60.70000076293945	24.100000381469727
11/12/2024, 11:30:17 μ.μ.	61	24.100000381469727
11/12/2024, 11:29:16 μ.μ.	61.099998474121094	24
11/12/2024, 11:28:16 μ.μ.	61.20000076293945	23.799999237060547
11/12/2024, 11:27:15 μ.μ.	61	23.899999618530273
11/12/2024, 11:26:15 μ.μ.	60.900001525878906	24
11/12/2024, 11:25:15 μ.μ.	60.599998474121094	24.100000381469727
11/12/2024, 11:24:14 μ.μ.	60.099998474121094	24.299999237060547

Refresh

Last 24 hours

Date	temperature avg
11/12/2024, 11:37:10 μ.μ.	25.103334426879883
11/12/2024, 11:31:47 μ.μ.	24.76332664489746
11/12/2024, 11:26:25 μ.μ.	25.139995574951172
11/12/2024, 11:21:03 μ.μ.	25.196664810180664
11/12/2024, 11:15:41 μ.μ.	24.85333251953125
11/12/2024, 11:10:19 μ.μ.	25.146663665771484
11/12/2024, 11:04:57 μ.μ.	25.306665420532227
11/12/2024, 10:59:35 μ.μ.	25.033336639404297
11/12/2024, 10:54:13 μ.μ.	25.223331451416016
11/12/2024, 10:48:50 μ.μ.	25.226661682128906
11/12/2024, 10:43:28 μ.μ.	25.206663131713867
11/12/2024, 10:38:06 μ.μ.	25.293336868286133
11/12/2024, 10:32:44 μ.μ.	25.90667152404785
11/12/2024, 10:27:22 μ.μ.	26.280000686645508
11/12/2024, 10:22:00 μ.μ.	26.206668853759766
11/12/2024, 10:16:38 μ.μ.	26.116662979125977
11/12/2024, 10:11:16 μ.μ.	26.033336639404297



Info
Last 24 hours
Live Temperature
6 s
24.1
0
C
50
Live Humidity
6 s
60.7
0
%
100
Control Led
24h All time data - Temperature & Humidity
1 m
80
70
60
50
40
30
20
00:00
02:00
04:00
06:00
08:00
10:00
12:00
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References / Bibliography

https://aws.amazon.com/what-is/iot/

https://www.nabto.com/guide-to-iot-esp-32/

https://howtomechatronics.com/tutorials/arduino/dht11-dht22-sensors-temperature-and-humidity-tutorial-using-arduino/

https://www.thethingsindustries.com/docs/integrations/cloud-integrations/thinger-io/

Image Sources

https://sfxpcb.com/how-to-use-a-breadboard-and-how-it-works/

https://gr.mouser.com/ProductDetail/Espressif-Systems/ESP32-C3-DevKitC-02?qs=stqOd1AaK7%2F1Q62ysr4CMA%3D%3D

https://grobotronics.com/humidity-sensor-dht11-module.html#group_108066796e4caad350-1

https://docs.arduino.cc/learn/electronics/lcd-displays/

https://learn.sparkfun.com/tutorials/how-to-use-a-breadboard/all

https://www.ladyada.net/learn/arduino/lesson3.html

https://www.technologicalarts.com/products/breadboard-jumper-wire-bundle-approx-65-pcs