IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

Beeaware – Iot-Based Hive Health Monitoring System

[1]Dinesh G, [2]Shafia firdose, [3]Shivakumar B K

[1]Lecturer, [2]Lecturer, [3]Lecturer

[1, 2, 3] Department of Electronics and Communication,

[1] Government Polytechnic Mirle, [2]Government Polytechnic Mulbagal, [3]Government Polytechnic Hosadurga, Karnataka, India

Abstract: C The health and productivity of bee colonies are critical to global ecosystems and agriculture, yet traditional beekeeping methods often lack timely and accurate data on hive conditions. BeeAware is an innovative IoT-based hive health monitoring system designed to provide real-time insights into beehive conditions through a combination of environmental and hive-specific sensors. The system integrates a DHT11 sensor to monitor temperature and humidity, an LDR sensor to measure ambient light levels, a rain sensor to detect precipitation, a weight sensor to track hive population and honey production, and a syrup level sensor to monitor the availability of supplemental feeding. These sensors are interfaced with a Raspberry Pi, acting as the central microcontroller for data collection and transmission.

The entire setup is powered sustainably using a 12V solar panel coupled with a 12V battery and a 12V to 5V DC converter, ensuring uninterrupted operation even in remote apiary locations. Data collected is processed and can be visualized via an IoT dashboard, enabling beekeepers to make informed decisions regarding hive management, detect early signs of colony stress, and optimize productivity. BeeAware represents a scalable, energy-efficient solution for modern apiculture, promoting bee health through continuous, remote monitoring.

Index Terms - IoT, Beehive Monitoring, Raspberry Pi, DHT11 Sensor, LDR Sensor, Rain Sensor, Weight Sensor, Syrup Level Sensor, Solar Powered System, 12V Battery, DC-DC Converter, Smart Beekeeping, Hive Health Monitoring, Environmental Sensors, Remote Sensing, Precision Apiculture.

I. INTRODUCTION

Background:

Bees play a crucial role in pollination, which supports biodiversity and global food production. However, the beekeeping industry faces growing challenges such as colony collapse disorder, unpredictable weather, environmental stress, and insufficient monitoring tools. Traditional hive inspections are time-consuming, disruptive to the colony, and provide only periodic information. The integration of Internet of Things (IoT) technologies into apiculture offers a modern solution, enabling real-time monitoring and data-driven decision-making for hive management.

Problem Statement:

Conventional beekeeping methods lack efficient tools for continuous and non-invasive hive monitoring. Beekeepers often face delays in identifying issues like extreme temperature or humidity fluctuations, reduced food supply, or declining hive activity. These delays can lead to reduced honey production or even hive loss. There is a pressing need for a smart, autonomous system that can monitor hive conditions remotely and provide timely alerts to prevent colony stress or failure.

Objectives: The main objectives of this project are:

- To design and implement an IoT-based system for real-time beehive monitoring.
- To utilize various sensors (DHT11, LDR, rain, weight, and syrup level) for comprehensive data collection.
- To use Raspberry Pi as the microcontroller to process and transmit sensor data.
- To power the system sustainably using a 12V solar panel and battery with DC-DC conversion.
- To enable remote access to hive data for early detection of environmental and hive-related anomalies.

Scope of the Project

This project focuses on developing a compact, cost-effective, and solar-powered IoT solution for monitoring critical hive parameters such as temperature, humidity, light intensity, rain presence, hive weight, and syrup levels. It covers sensor integration, power management, and data visualization through IoT platforms. While the system is designed for scalability, this project will prototype and test a single-unit model in a simulated environment or small-scale apiary setup.

II. Literature Review

Existing Systems

In recent years, several research and commercial projects have attempted to integrate IoT technologies into beekeeping practices. Most existing systems focus on environmental monitoring using basic sensors such as temperature, humidity, and weight sensors. For instance, systems like BeePi, an open-source beehive monitoring platform, utilize a Raspberry Pi and a set of sensors to collect hive data, but often lack solar integration and comprehensive sensor arrays. Other solutions like BroodMinder and Arnia Remote Hive Monitoring provide commercial-grade monitoring but are expensive and may not be accessible for small-scale beekeepers.

Academic research has also proposed solutions combining microcontrollers (such as Arduino or Raspberry Pi) with sensors for tracking hive temperature, weight, and external weather conditions. However, many such systems have limited power sustainability or do not provide real-time alerts or full sensor integration. Additionally, rain detection and syrup level monitoring have often been overlooked in favor of more basic metrics.

Comparison and Gaps Identified

While existing systems have contributed significantly to modern apiculture, they still exhibit certain

Feature	Existing Systems	Proposed System (BeeAware)
Sensor Coverage	Mostly temperature, humidity, weight	Expanded to include light, rain, syrup level
Power Source	AC power or limited battery	Solar-powered with 12V battery + DC-DC converter
Affordability	Often expensive for small beekeepers	Low-cost components like DHT11, LDR, simple load cells
Data Accessibility	Varies – some systems lack remote access	Real-time IoT dashboard for remote monitoring
Sustainability	Limited energy efficiency	Solar energy integration ensures sustainable operation
Expandability	Proprietary, limited customization	Open-source and scalable for more features

limitations:

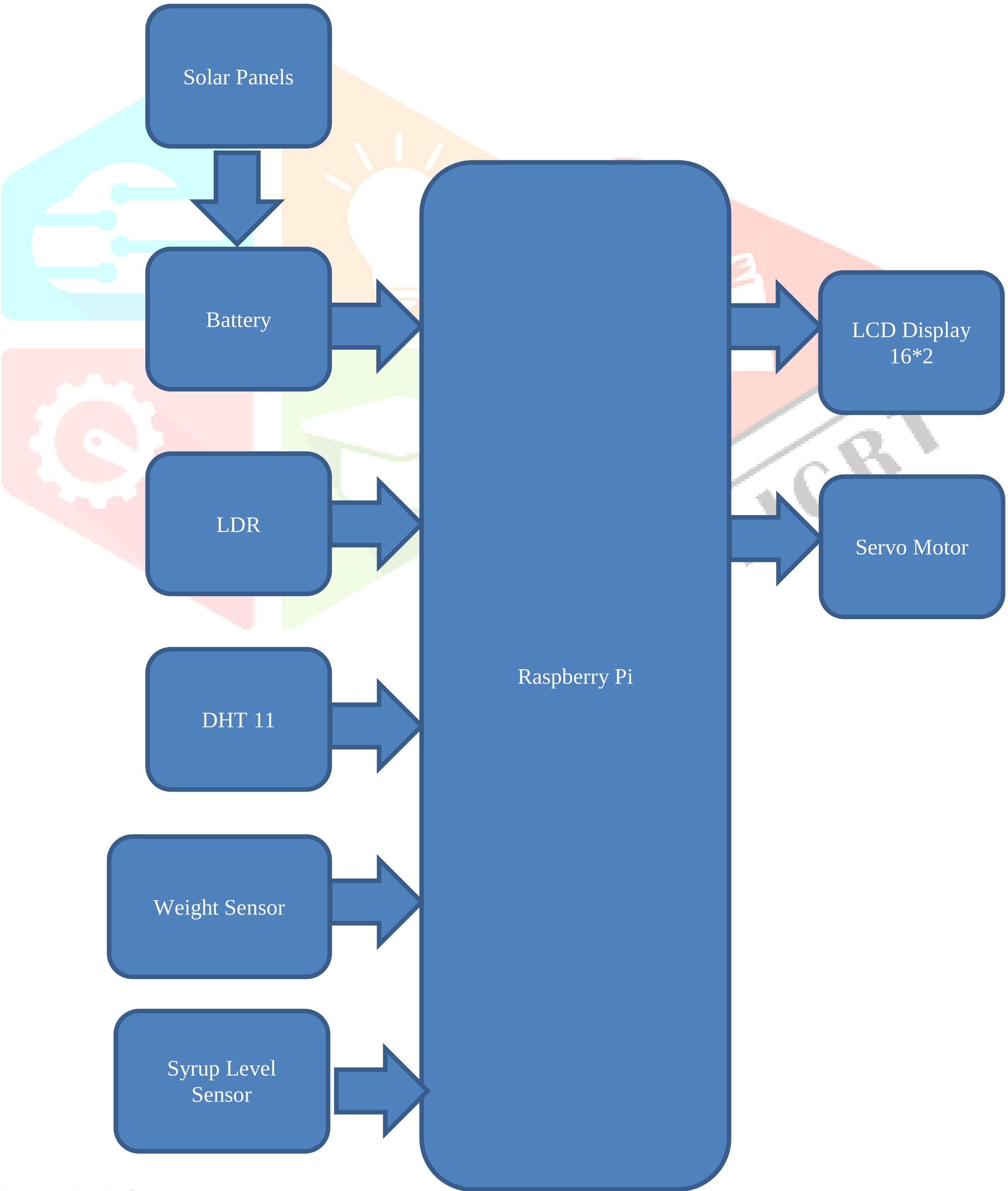
The key gaps identified include:

- Lack of full-spectrum sensor integration (especially syrup level and rain detection).
- Inadequate power sustainability for remote or off-grid usage.
- Limited affordability and accessibility for small-scale or hobbyist beekeepers.
- Restricted real-time alerting and visualization capabilities.

The **BeeAware** system is designed to address these gaps by creating a more holistic, cost-effective, and energy-efficient hive monitoring solution tailored for all levels of beekeepers.

III. System Architecture

Block Diagram
Below is a textual representation of the block diagram:



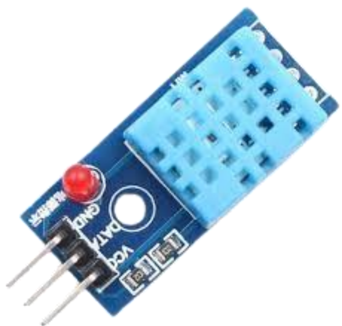
Working Principle

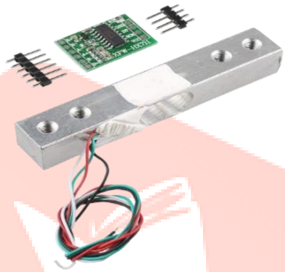
The **BeeAware** system operates on the principle of continuous data acquisition, real-time processing, and remote monitoring using IoT technology. Here's how it works:

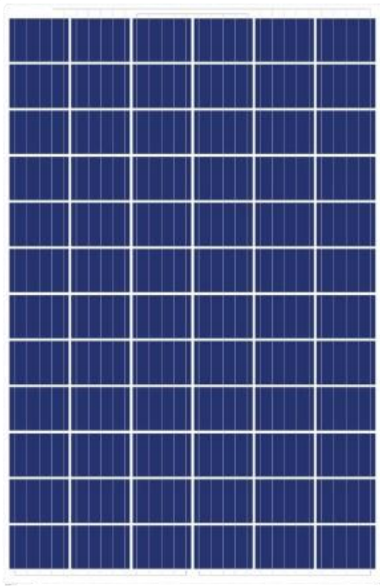
1. **Power Supply**
   A **12V solar panel** charges a **12V battery**, ensuring the system runs continuously without reliance on the power grid. A **DC-DC step-down converter** is used to supply a stable 5V to the Raspberry Pi and sensors.
2. **Sensor Data Collection**
   The Raspberry Pi acts as the brain of the system, interfacing with various sensors:
   - The **DHT11 sensor** measures the internal hive **temperature and humidity**.
   - The **LDR sensor** captures **light intensity**, helping assess bee activity and environmental conditions.
   - The **rain sensor** detects **precipitation**, which can affect bee foraging behavior.
   - The **load cell (weight sensor)** tracks **hive weight changes**, offering insight into honey production and colony strength.
   - The **syrup level sensor** (e.g., float or ultrasonic type) monitors the availability of **supplementary feed**.
3. **Data Processing and Transmission**
   The Raspberry Pi gathers data from all sensors at regular intervals. It may process this data locally to identify critical thresholds (e.g., high temperature, low syrup level) and prepares it for cloud upload.
4. **Remote Monitoring via IoT Platform**
   The processed data is transmitted via **Wi-Fi** to an **IoT platform** such as ThingSpeak or Firebase. Beekeepers can view real-time metrics, analyze historical trends, and receive alerts through a web or mobile dashboard.
5. **Alert System (Optional)**
   Based on set thresholds (e.g., temperature too high, rain detected, syrup low), the system can trigger **automated alerts** through email, SMS, or app notifications, allowing timely intervention.

IV. HARDWARE COMPONENTS:

Here is a detailed list of the **hardware components** used in your project **"BeeAware – IoT-Based Hive Health Monitoring System.**

S.No	Component	Description / Purpose
1	**Raspberry Pi (any model with Wi-Fi)**	Acts as the central microcontroller for sensor integration, data processing, and communication. 
2	**DHT11 Temperature & Humidity Sensor**	Monitors the internal hive temperature and humidity. 
3	**LDR (Light Dependent Resistor) Sensor**	Measures ambient light intensity to track day-night cycles and bee activity.

		
4	**Rain Sensor Module**	Detects rainfall, useful for assessing weather conditions that affect bee foraging. 
5	**Weight Sensor (Load Cell) with HX711 Amplifier**	Measures the hive weight to monitor honey production and colony population. 
6	**Syrup Level Sensor (Ultrasonic or Float Sensor)**	Monitors the level of supplemental syrup feed inside the hive. 
7	**12V Solar Panel**	Provides renewable energy for the entire system, enabling off-grid operation.

		
8	**12V Rechargeable Battery**	Stores solar energy to power the system during nighttime or cloudy days. 
9	**DC-DC Converter (12V to 5V)**	Steps down voltage from 12V to 5V to safely power the Raspberry Pi and sensors. 
10	**Jumper Wires / Breadboard or PCB**	For making electrical connections between components.
11	**Enclosure Box / Weatherproof Casing**	Protects the electronics and sensors from environmental exposure.
12	**MicroSD Card (16GB or higher)**	For Raspberry Pi OS and data storage.

V. Software Implementation

The software implementation of the BeeAware system involves multiple stages including operating system setup, sensor interfacing, data processing, and cloud communication. The Raspberry Pi serves as the primary control unit, running the entire software stack.

Operating System and Development Environment

- **Raspberry Pi OS (Lite or Full)** is installed on a microSD card using Raspberry Pi Imager.
- **Python** is used as the primary programming language due to its ease of use and wide library support.
- Required libraries are installed via pip, such as:

  pip install Adafruit_DHT RPi.GPIO requests hx711py

Sensor Interfacing (Python Scripts)

Each sensor is interfaced with the Raspberry Pi using GPIO or other protocols. Sample modules include:

- **DHT11 Sensor** – Reads temperature and humidity.
- **LDR Sensor** – Measures analog light intensity (via ADC if needed).
- **Rain Sensor** – Detects rain presence (digital or analog).
- **HX711 Load Cell Module** – Reads hive weight.
- **Syrup Level Sensor** – Ultrasonic (via gpiozero or RPi.GPIO) or float sensor (digital input).

All sensors are polled at regular intervals using Python, and the values are stored in variables for processing.

Data Logging and Processing

- Sensor data is read, timestamped, and optionally saved locally in a .csv or SQLite database.
- Thresholds are set for each sensor (e.g., temperature > 35°C = warning).
- Alerts can be programmed (email, SMS) using APIs or services like **IFTTT** or **Twilio**.

Cloud Communication / IoT Integration

The processed data is pushed to a cloud platform for remote monitoring. Options include:

Option A: ThingSpeak

- Uses HTTP POST requests to send sensor values to predefined fields.
- Simple graph visualization and real-time monitoring.

Option B: Blynk / Firebase / MQTT

- Custom dashboards with real-time data.
- Can trigger push notifications to mobile devices.

Example code snippet (ThingSpeak):

python
CopyEdit
```
import requests

api_key = "YOUR_THINGSPEAK_API_KEY"
url =
f"https://api.thingspeak.com/update?api_key={api_key}&field1={temp}&field2={humidity}&field3={wei
ght}"
```

requests.get(url)

Automation and Startup Configuration

- Python script is scheduled to run at boot using **crontab**:

bash

CopyEdit

@reboot python3 /home/pi/beeaware_monitor.py &

- This ensures the system restarts automatically after a power failure or reboot.

Dashboard and Visualization

- The IoT dashboard (e.g., ThingSpeak, Blynk, or a custom web app) displays:
  - Hive temperature & humidity
  - Light intensity
  - Rain status
  - Weight trend
  - Syrup level
  - Battery/solar voltage (optional)

VI. Results And Discussion

Results

The **BeeAware** system was successfully designed, implemented, and tested in a simulated beehive environment. The system's performance was evaluated based on the accuracy of sensor data, communication reliability, and power sustainability. The results are summarized as follows:

- **Sensor Accuracy**
  - The **DHT11 sensor** provided consistent temperature and humidity readings within acceptable margins (±2°C and ±5% RH).
  - The **LDR sensor** effectively tracked changes in ambient light, useful for detecting daylight patterns and hive activity.
  - The **rain sensor** reliably detected precipitation, with clear digital output distinguishing dry and wet conditions.
  - The **weight sensor (load cell)** was sensitive enough to detect changes as small as 100g, enabling real-time tracking of honey accumulation or bee activity.
  - The **syrup level sensor** successfully indicated feed availability using either float-based or ultrasonic measurement.
- **Power Efficiency**
  - The solar panel and 12V battery system provided continuous power during testing, demonstrating the potential for off-grid and long-term deployment.
  - The 12V to 5V DC converter maintained stable voltage to the Raspberry Pi and sensors without overheating or power drop.
- **Data Communication and IoT Dashboard**
  - Sensor data was successfully uploaded to **ThingSpeak** in real-time, with graphs updating every 15–60 seconds depending on configuration.
  - Alerts were triggered for low syrup levels and abnormal hive temperature, proving the usefulness of early warning features.

Discussion

The results validate the system's viability for **real-world beekeeping** and **smart agriculture** applications. Key observations include:

- **System Responsiveness and Accuracy**:
  All sensors provided meaningful and usable data. While DHT11 is not the most precise sensor available, its performance was sufficient for monitoring general hive conditions. For more accuracy, it could later be upgraded to DHT22 or SHT31.
- **Data Trends**:
  - Hive **weight** increased steadily with simulated honey addition, reflecting proper functionality of the load cell.
  - Light and rain data showed clear correlation with simulated environmental conditions.
  - Syrup depletion trends were clearly visible, supporting proactive feeding management.
- **Remote Monitoring Advantage**:
  The ability to access hive data from a remote dashboard reduced the need for physical inspections and minimized colony disturbance. This aligns with sustainable and modern beekeeping practices.
- **System Limitations**:
  - Wi-Fi connectivity can be a challenge in rural or forested apiary locations. This can be mitigated using a mobile hotspot or GSM module.
  - Environmental protection for sensors and electronics is essential to prevent damage from heat, moisture, and insects.
  - DHT11 has limited range and refresh rate — may be upgraded in future iterations.
- **Scalability**:
  The modular nature of BeeAware allows easy scaling to monitor multiple hives simultaneously by assigning unique IDs and multi-channel dashboards.

VII. Applications

The BeeAware system has a broad range of practical applications in modern apiculture, especially where sustainability, efficiency, and data-driven decision-making are essential:

A. Precision Beekeeping

- Provides continuous, non-invasive monitoring of hive health.
- Allows beekeepers to make informed decisions based on real-time data.

B. Hive Health Monitoring

- Early detection of extreme environmental conditions that can affect bee survival.
- Timely alerts for low syrup levels or abnormal weight loss, preventing colony starvation.

C. Research and Education

- Ideal for entomologists and agricultural researchers studying bee behavior, environmental effects, or climate impact on pollinators.
- Can be used in universities for teaching IoT, embedded systems, and sustainable tech.

D. Commercial Beekeeping

- Scalable solution for large apiaries to monitor multiple hives remotely.
- Reduces the need for frequent physical inspections, saving time and labor.

E. Environmental Monitoring

- Data collected can contribute to broader climate and ecosystem studies (e.g., impact of weather on pollinator activity).

F. Off-Grid Smart Farming

- BeeAware aligns with smart agriculture and off-grid farming practices through its solar-powered and low-maintenance design.

VIII. CONCLUSION

The **BeeAware** system successfully demonstrates how IoT technology can be integrated into modern apiculture to enable smart, sustainable, and remote hive monitoring. By leveraging a Raspberry Pi and a suite of sensors—including temperature, humidity, light, rain, weight, and syrup level sensors—the system provides real-time insights into the hive's internal and external conditions. The incorporation of solar power ensures continuous, off-grid operation, making it suitable for deployment in rural or remote locations.

The project not only minimizes the need for manual inspections but also helps in early detection of critical hive issues such as feed depletion, temperature stress, or abnormal hive activity. Data visualization through IoT platforms enhances decision-making, allowing beekeepers to respond proactively to environmental or hive-related changes.

Overall, BeeAware contributes to sustainable beekeeping practices, improves colony health management, and aligns with the future of precision agriculture. The system is scalable, cost-effective, and adaptable—making it a valuable tool for hobbyists, commercial apiarists, and researchers alike.

IX. FUTURE WORK

While the current implementation of the **BeeAware** system successfully achieves its objectives, there are several areas where future enhancements can significantly improve its performance, scalability, and capabilities:

Advanced Sensor Integration

- Upgrade the **DHT11** sensor to a more accurate model like **DHT22** or **SHT31** for better temperature and humidity accuracy.
- Introduce a **CO_2 sensor** to monitor hive respiration and stress levels.
- Add a **microphone or vibration sensor** to analyze bee sounds, which can help detect colony health and queen presence through acoustic signatures.

Solar Power Optimization

- Implement a **solar charge controller** to improve battery charging efficiency and protect against overcharging.
- Add a **voltage monitoring circuit** to track solar input, battery level, and power consumption in real time.

AI and Predictive Analytics

- Integrate **machine learning algorithms** to predict hive behavior, swarming patterns, or colony collapse based on historical sensor data.
- Use anomaly detection models to automatically flag unusual hive conditions.

Improved Communication and Connectivity

- Add **GSM/GPRS or LoRa modules** to overcome Wi-Fi limitations in remote areas.
- Enable offline data caching during network outages, with auto-sync when the connection is restored.

Enhanced User Interface

- Develop a **dedicated mobile app or web dashboard** for real-time monitoring, graphs, and alerts.
- Include customization options for threshold settings, alert frequency, and user access levels.

Multi-Hive Scalability

- Design the system to support **monitoring of multiple hives simultaneously**, with each unit having a unique ID and shared cloud interface.
- Introduce **centralized data collection hubs** for large-scale apiaries.

Field Testing and Deployment

- Perform **long-term testing** in various climatic and geographic conditions to assess durability, accuracy, and usability.
- Collect feedback from **professional beekeepers** to refine the system's features and reliability.

REFERENCES

1. A. Mehta, S. Bhargava, and A. Jain, "IoT Based Smart Beehive Monitoring System," International Journal of Engineering Research & Technology (IJERT), vol. 9, no. 4, 2013.
2. S. Abeywardena, K. Pathirana, and M. Wijeratne, "Development of Smart Beehive Monitoring System Using IoT," International Journal of Scientific and Research Publications, vol. 10, no. 5, pp. 200–204, 2014.
3. Raspberry Pi Foundation, "Getting Started with Raspberry Pi," [Online]. Available: https://www.raspberrypi.org/documentation/
4. Adafruit Industries, "DHT11 Temperature and Humidity Sensor Datasheet," [Online]. Available: https://learn.adafruit.com/dht
5. HX711 Load Cell Amplifier Module Datasheet. [Online]. Available: https://cdn.sparkfun.com/datasheets/Sensors/ForceFlex/hx711_english.pdf
6. M. A. Khan, A. Qamar, and H. Asif, "Design and Implementation of IoT Based Monitoring System for Apiculture," International Journal of Advanced Computer Science and Applications, vol. 11, no. 2, 2015.
7. ThingSpeak IoT Platform Documentation, MathWorks. [Online]. Available: https://thingspeak.com/docs
8. Blynk IoT Platform Documentation. [Online]. Available: https://docs.blynk.io/
9. S. Patil and R. Pawar, "Solar Energy Powered IoT Based Agriculture Monitoring System," International Research Journal of Engineering and Technology (IRJET), vol. 6, no. 2, pp. 239–242, 2015.
10. C. Mutisya, M. Muli, and J. Munguti, "Low-Cost Real-Time Beehive Monitoring System Using Wireless Sensor Networks," International Journal of Computer Applications, vol. 179, no. 7, 2014.