PROJECT ABSTRACT

IoT Beehive Monitor using ESP32

An ESP32-based non-invasive beehive monitor tracking in-hive temperature, humidity and hive weight, with a swarm-risk heuristic, MQTT dashboard and solar deep-sleep operation. Delivered built-to-order with working prototype, firmware, dashboard, report, PPT and viva kit.

01. Title

IoT Beehive Monitor using ESP32

02. Introduction / Background

Beekeepers still assess colony health by opening hives — disruptive to the bees, infrequent, and easy to postpone until a problem is advanced. Between inspections a lost queen, an overheating brood nest, excess moisture or a pre-swarm buildup can develop unseen for days. The three signals that matter most can be measured without opening the box: brood-box temperature, humidity, and total hive weight, whose multi-day trend reflects honey stores and foraging activity. The ESP32 is a natural fit for the node: Wi-Fi telemetry, deep-sleep power modes for battery life, and interfaces for both a digital climate sensor and a load-cell amplifier. This project implements the complete monitor: the sensor node in a weatherproof enclosure, buyer-run load-cell calibration, threshold and swarm-heuristic logic, and an MQTT dashboard with gauges, climate charts, weight trends and an event log.

03. Problem Statement

Manual hive inspection is disruptive and infrequent, while commercial hive monitors are expensive and closed. The project addresses this gap with a low-cost, student-built IoT node that watches hive climate and weight continuously and non-invasively: temperature and humidity from a DHT22 in the brood box, weight from a load cell under the stand, trends and threshold alerts on an MQTT dashboard, and a documented calibration procedure so every reading is meaningful on the student's own hive stand.

04. Objectives

- Sense in-hive temperature and humidity with a DHT22 on configurable wake cycles.
- Track hive weight with a load cell and HX711 amplifier as a trend proxy for stores and foraging.
- Implement threshold alerts and a swarm-risk inspection heuristic in firmware.

- Publish telemetry over MQTT to a multi-hive dashboard with gauges, charts and event log.
- Operate on battery with solar charging using ESP32 deep sleep between readings.
- Provide a buyer-run tare and known-weight calibration procedure for the load cell.
- Deliver the complete student kit: prototype, firmware, dashboard, report, PPT and viva Q&A.

05. Proposed Methodology

The system is developed in three layers. (1) Sensing: a DHT22 in the brood box and a load cell with HX711 under the hive stand, read on each wake cycle with averaging. (2) Node logic: the ESP32 compares readings with configured thresholds, evaluates the swarm heuristic from sustained temperature elevation plus weight-pattern changes, publishes over MQTT, then returns to deep sleep; missed uploads are buffered and backfilled. (3) Dashboard: per-hive gauges, 24-hour climate charts, a 7-day weight trend and a timestamped event log for up to four hives. The student calibrates the load cell once with known weights using the included procedure.

06. System Architecture / Working

On each wake cycle the ESP32 reads the DHT22 and the HX711, compares the values with thresholds, and evaluates the swarm heuristic. Data is published via MQTT with the hive ID; the dashboard renders live gauges, appends to the climate chart and weight trend, and logs threshold crossings. Between configurable 5–30 minute cycles the node deep-sleeps on its 18650 cell, topped up by a small solar panel. A local OLED shows the last reading at the hive, and Wi-Fi outages only delay the dashboard — sensing and buffering continue.

07. Hardware / Software Requirements

- ESP32 development board (Wi-Fi, deep sleep)
- DHT22 temperature-humidity sensor
- Load cell with HX711 24-bit amplifier
- 0.96-inch OLED display
- 18650 cell with solar charging module
- Weatherproof enclosure and hive-stand mounting hardware
- MQTT broker plus web dashboard
- Arduino IDE (C/C++ firmware)

08. Expected Outcomes

- A working hive node reporting temperature, humidity and weight on schedule.
- A multi-hive MQTT dashboard with gauges, climate charts, weight trend and event log.

- A calibrated load-cell chain with a documented tare/known-weight procedure.
- Threshold and swarm-heuristic alerting demonstrated on the student's own test data.
- A complete report, PPT and viva Q&A covering sensors, MQTT, power design and calibration.

09. Applications

- Apiary monitoring for beekeepers and apiculture training centres.
- Teaching sensor interfacing, load-cell calibration and IoT telemetry.
- Demonstrating trend-based analysis and deep-sleep power design.

10. Future Scope

- Acoustic analysis of hive buzz as an additional colony-health channel.
- LoRa backhaul for apiaries beyond Wi-Fi range.
- Automated varroa-treatment reminders driven by weight and season data.
- Mobile app with push alerts for threshold crossings.