Documentation

Smart Home Energy Monitoring System

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Submission: Real-time simulation of energy usage, local storage, and cloud dashboard
Tools: Python, Flask, SQLite/CSV, FreeRTOS-style task scheduling

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Project Objective

To build a simulated smart embedded system that:

- Monitors energy usage of 3 appliances
- Stores data locally
- Sends data to a cloud server
- Visualizes real-time energy statistics

Overview

This project simulates a **Smart Home Energy Monitoring System** using Python for embedded-like simulation and a Flask server for data visualization. Sensor readings are randomly generated (no physical ESP device is used). Data is logged locally and published via simulated MQTT to a server that stores, analyzes, and displays energy usage per device.

Project Structure

📁 embedded/

├── main.py   # Simulates sensor data generation and MQTT communication

├── local_storage.py   # Handles local CSV logging

├── mqtt_client.py   # Simulates MQTT publish to server endpoint

└── utils.py   # Helper utilities for data generation

📁 server/

├── server.py   # Flask server to receive and display energy data

└── templates/

  └── dashboard.html   # Dashboard UI to visualize statistics

📁 data/logs/

├— sensor_log.csv # Local CSV log of generated sensor data

└— comm_log.txt # Log of communication and MQTT publishing

📁 docs/

├— architecture.pdf # Architecture diagram of the system

├— schema.png # Flowchart/system schema

└— report.md # This documentation file

📁 demo/

└— demo.mp4 # (To be recorded) Walkthrough of the system in action

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System Components

1. Embedded Simulation

- main.py: Generates random power values for devices and sends data to server.
- **local_storage.py**: Logs data in sensor_log.csv for traceability.
- **mqtt_client.py**: Mimics MQTT behavior by sending POST requests to Flask server.
- utils.py: Generates device IDs, timestamps, and simulated power values.

2. Server & Visualization

- server.py: Flask server that receives POST data on /energy, stores in memory, and renders an HTML dashboard on /dashboard.
- **dashboard.html**: Renders a table of average, max, and min power usage by device.

3. Logs & Documentation

- **sensor_log.csv**: CSV log file of each generated reading.
- **comm_log.txt**: Logs all communication and errors.
- **schema.png**: System flowchart.
- **architecture.pdf/png**: High-level architecture diagram.

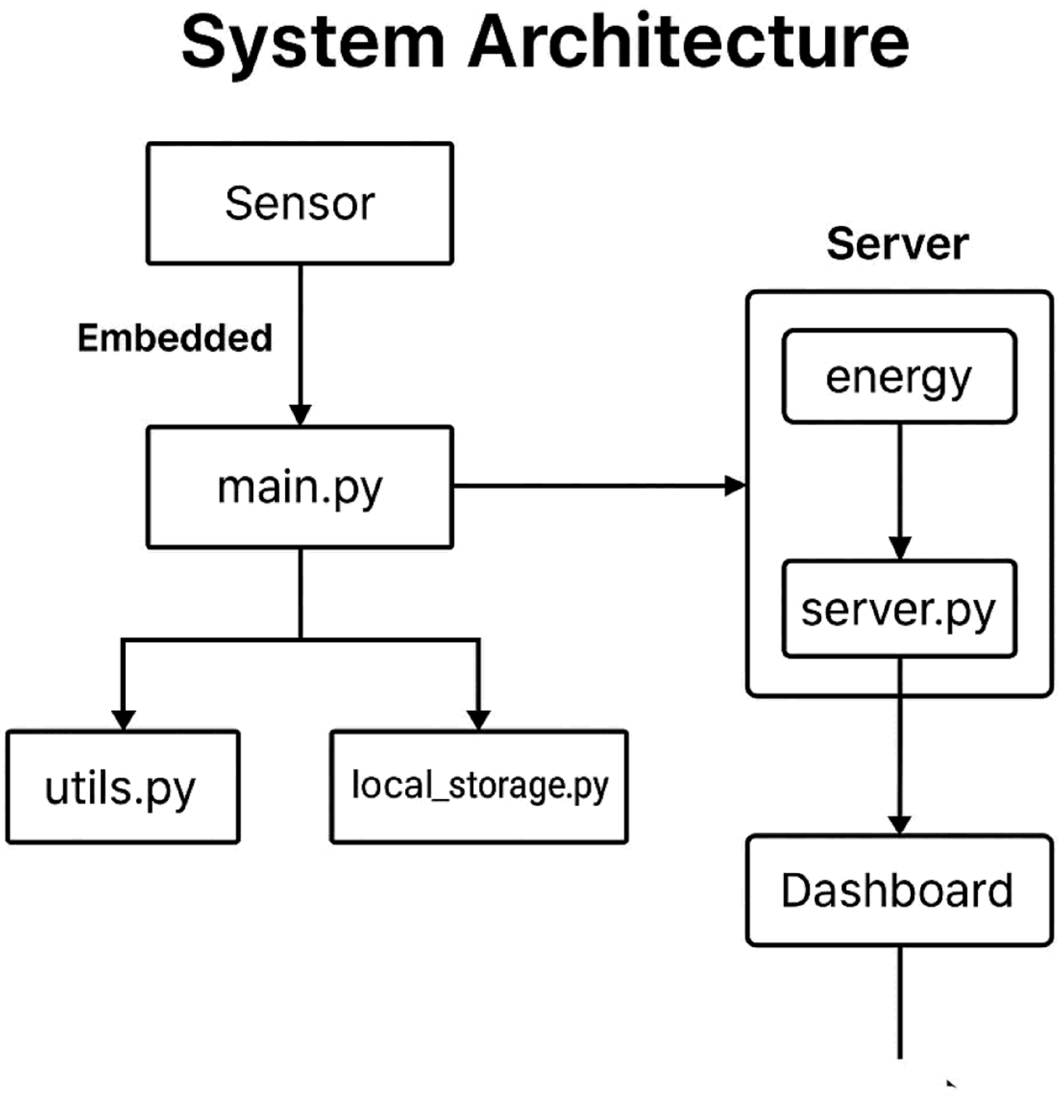
Data Flow Summary

1. main.py generates synthetic readings per device every few seconds.
2. Each reading is:

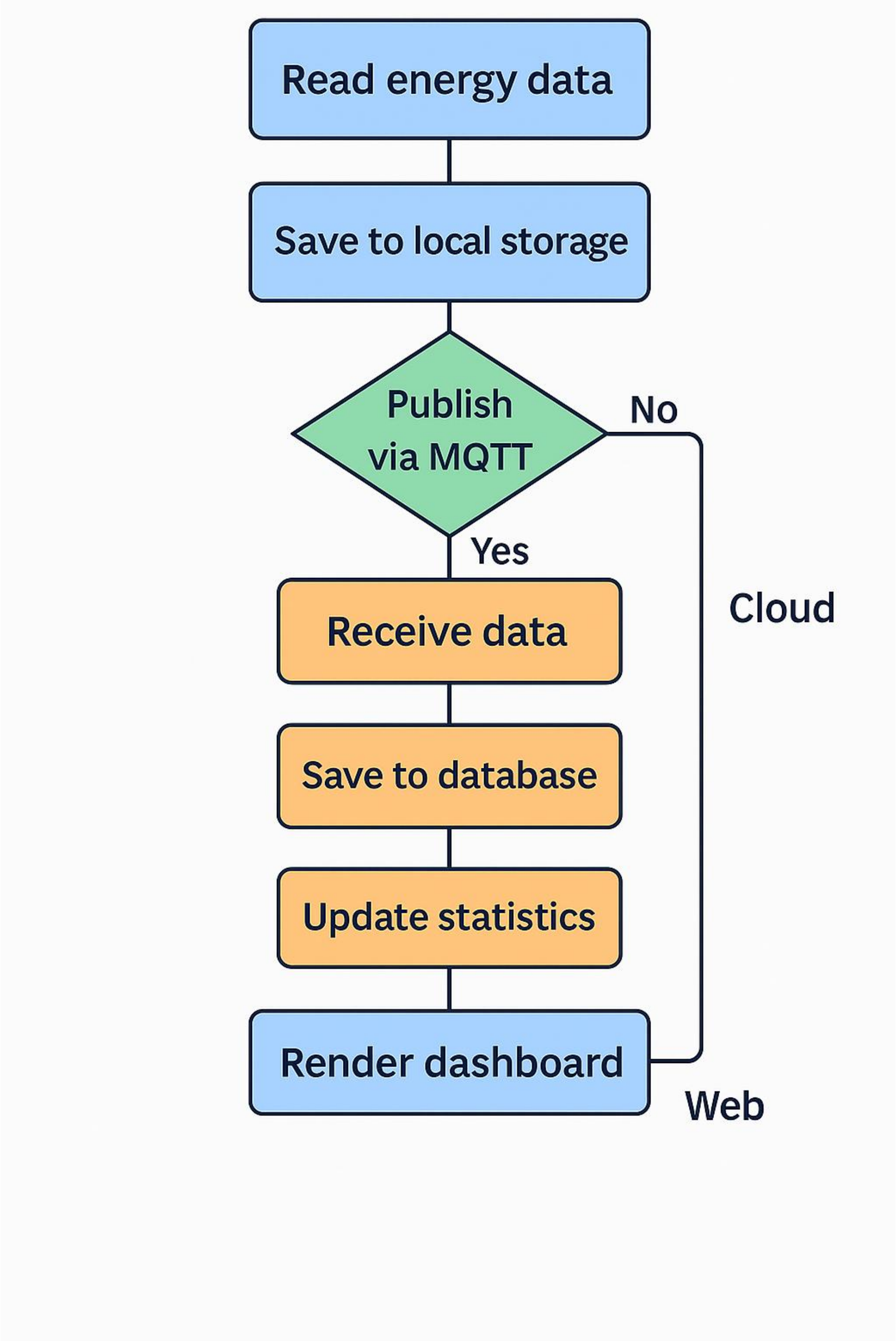
    - Logged locally in sensor_log.csv
    - Sent via simulated MQTT (HTTP POST) to Flask server

3. Server receives and stores data in memory.
4. Visiting /dashboard shows aggregated power usage per device.

Architecture Diagram



System Schema (Flowchart)



Simplified System Architecture

[Simulated Sensors]

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[Task Scheduler]

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[Local Storage (CSV)]

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[HTTP POST (Client)]

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[Flask Cloud Server]

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[Dashboard (HTML)]

Technologies Used

- Python: Core programming
- Flask: Cloud simulation
- CSV Files: Lightweight local storage
- Simulated Sensors: Randomized power readings

Features Implemented

Feature
1.Real-time task simulation
2.Sensor data generation
3.Local CSV file logging
4.Communication via HTTP
5.Error handling + retries
6.Flask server + dashboard

Feature
7.Dashboard stats (avg/max)

Database Schema (CSV Format)

Column Name	Description
device_id	Unique ID of appliance
timestamp	Date-time of reading
power	Power usage in watts

Problems Faced & Solutions

Problem	Solution
Flask timeouts on large payloads	Reduced batch size
Local file write errors	Added exception + logging mechanism
Network simulation delays	Used time.sleep() with retry logic
Dashboard not updating dynamically	Used in-memory list + timestamp updates

How to Run

Step 1: Start the Flask Server

```
cd server
```

```
python server.py
```

Visit: http://localhost:5000/dashboard

Step 2: Simulate Sensor Data

Open a new terminal:

```
cd embedded
```

```
python main.py
```

You will see periodic readings being sent to the server and logged locally.

Demo Recording (demo.mp4)

Record a short walkthrough showing:

- Running the server and embedded script
- Visiting the dashboard
- Live data updates

Status

- Local simulation without ESP
- Local storage with CSV
- Flask server for data collection
- HTML dashboard with analytics
- Diagrams and documentation complete

Sample Output

```
AC001,2025-04-10 12:02:00,1450.1

WM002,2025-04-10 12:02:00,700.4

FR003,2025-04-10 12:02:00,243.3
```

Access dashboard at: http://localhost:5000/dashboard