Documentation

Smart Home Energy Monitoring System

Date: April 11, 2025
Submission: Real-time simulation of energy usage, local storage, and cloud dashboard
Tools: Python, Flask, SQLite/CSV, FreeRTOS-style task scheduling

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
```

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

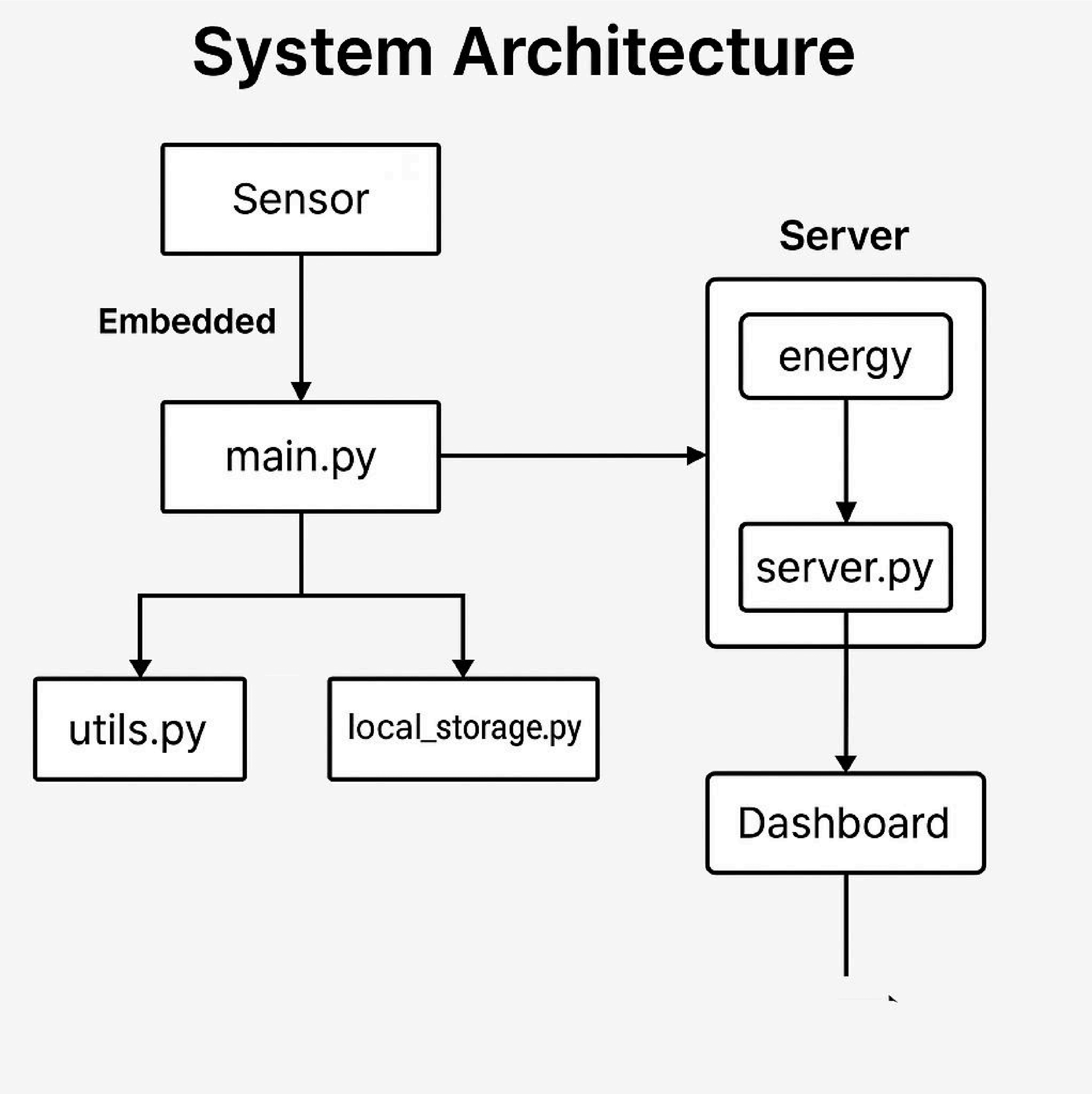
- **sensor_log.csv**: CSV log file of each generated reading.
- **comm_log.txt**: Logs all communication and errors.

- **schema.png**: System flowchart.
- **architecture.pdf/png**: High-level architecture diagram.

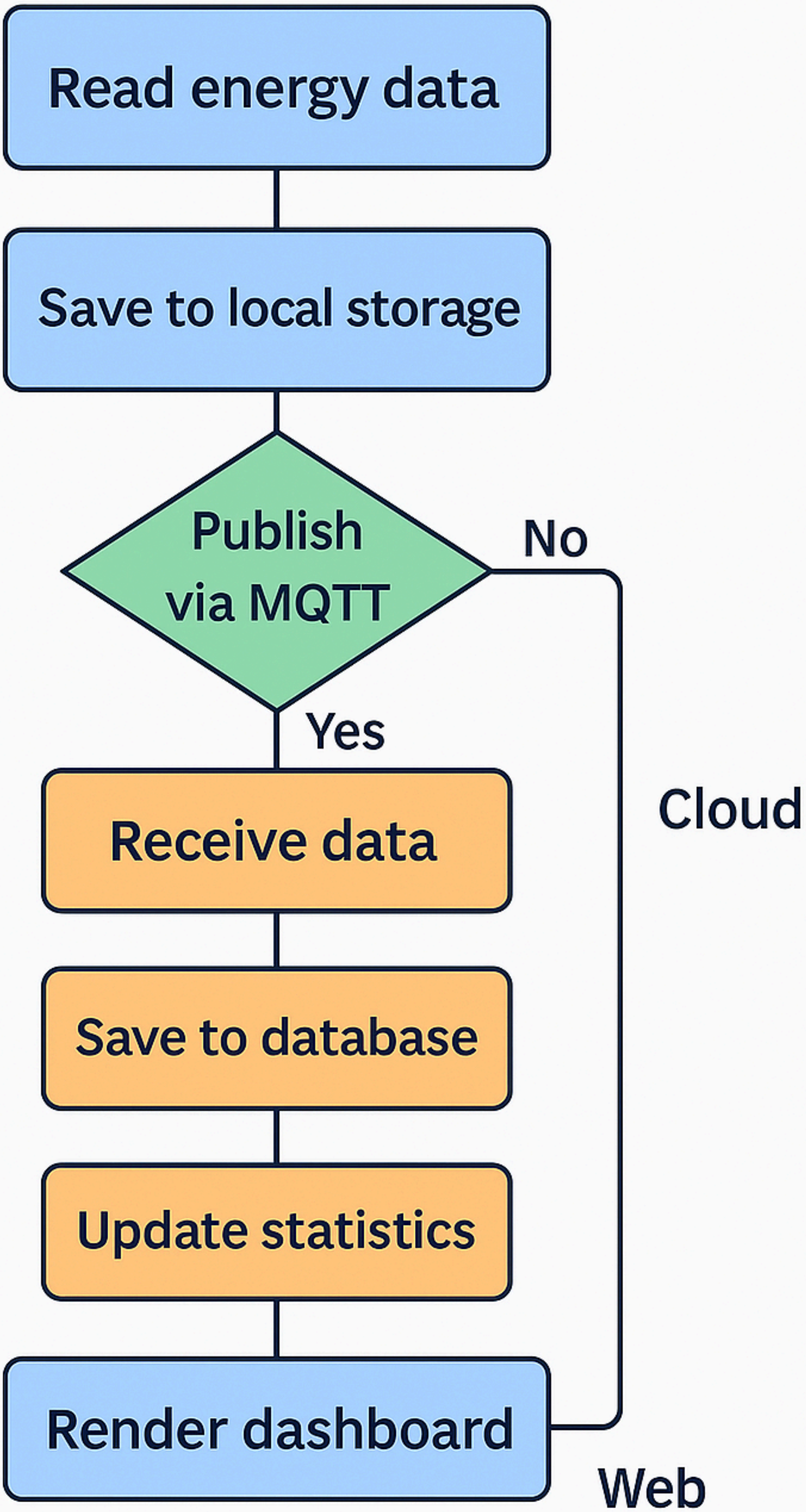
Data Flow Summary

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)


Read energy data
Save to local storage
Publish via MQTT
No
Yes
Cloud
Receive data
Save to database
Update statistics
Render dashboard
Web

Simplified System Architecture

```
[ Simulated Sensors ]
       ↓
[ Task Scheduler ]
       ↓
[ Local Storage (CSV) ]
       ↓
[ HTTP POST (Client) ]
       ↓
[ Flask Cloud Server ]
       ↓
[ 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
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