Final Prototype Test Report

Team 27
Domus: Smart Home Control

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1 Required Materials

1.1 Hardware:

- Raspberry Pi 5 (with 32GB Amazon Basics microSDXC Class 10 memory card)
- 2 ESP32 Devkit S1 Micontrollers
- Raspberry Pi 4B
- BME688 Sensor
- Raspberry Pi AI Camera IMX 500
- HC-SR501 Motion sensor
- TP Link KP115 Smart Plug
- Verizon Wifi Router
- Housing Units

1.2 Software:

- Python scripts:
    - Collecting real-time sensor data (hosted using a Flask Server - using WebSocket for real-time alerting)
    - Kasa API to link smart plug data to our app
    - Streamed live video footage using Gstreamer Pipeline
    - Face Recognition using dlib + OpenCV
    - Object Detection using MobileNet SSD V2
    - Activity Recognition using MoveNet + LSTM
- React Native:

- Integrated sensor data and face recognition functionality through iOS mobile application.

2 Set Up

The Raspberry Pi 5 serves as the central processor, managing data collection and processing for the smart home system. ESP32 microcontrollers, powered via wall outlets for safety, collect sensor data and transmit it wirelessly to the Pi 5, where Python scripts handle processing. A Raspberry Pi 4, connected to the Raspberry Pi AI camera via MIPI CSI, acts as a dedicated edge device, streaming video wirelessly to the central Pi. An iOS app displays real-time sensor data, supporting features like theft detection, motion sensing, environmental monitoring, and energy tracking. Theft detection is powered by a face recognition model using OpenCV and face_recognition from the dlib library.

2.1 Pre-testing Setup Procedure

1. Power On the required devices
    a. Connect the Raspberry Pi 5 to a power source using its USB-C cable. Ensure the preloaded microSDXC card is already inserted.
    b. Connect the Raspberry Pi 4 to a power source using its USB-C cable.
    c. Connect the Kasa Smart Plug to any appliance of your choice
    d. Connect the edge sensors to wall sockets (could be any desirable space in the house as per the user)

2. Open the Domus Application
    a. Log in to the application using your Gmail account
    b. Go to the “Devices” screen on the application and follow the instructions to add the motion sensor and temperature sensor.
    c. Go back to the home page and make sure relevant real-time data is displayed.

3. Feature Verification
    a. Navigate to each screen in the app to verify that:
        i. **Home Screen**: This screen displays the relevant data in terms of connected sensors.
        ii. **Energy Screen**: The screen is set up to display current power/total energy consumption metrics in the form of time graphs.
        iii. **Devices Screen**: The screen allows you to add new sensors by sending your WiFi credentials to the new, local ESP32.
        iv. **Surveillance Screen**: This screen within the mobile application displays real-time alerts of unknown/authorized personnel appearing in the camera’s frame.

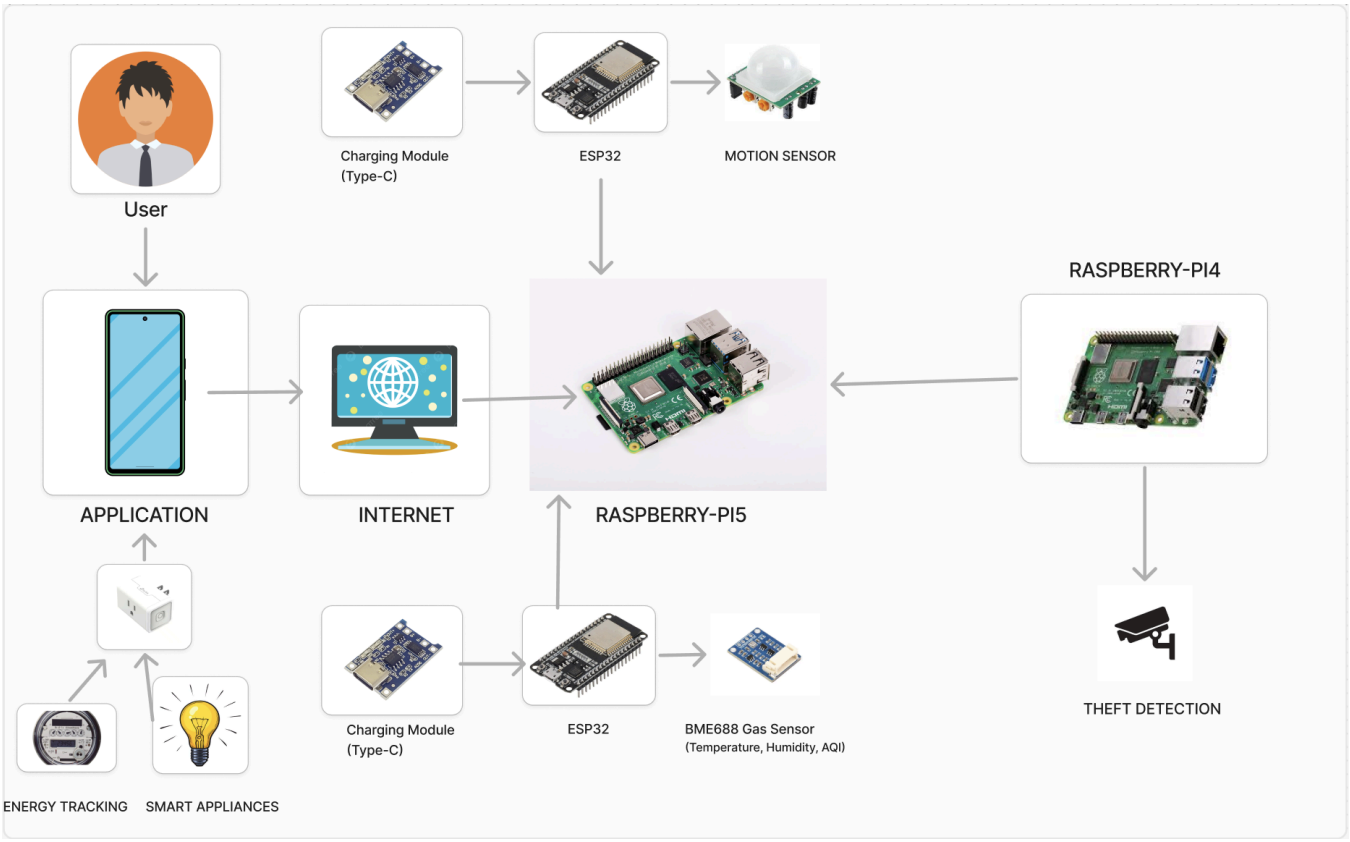


Figure 1: *Illustration of Setup and Process Flow*

2.2 Testing Procedure

1. **Live Motion Detection:** Wave hand in front of sensor (from up to 7 metres away)
2. **Face Recognition:** Should generate alerts for unknown/authorized personnel present in the camera's field of view in real time.
3. **Object Detection:** Display various objects in the camera's frame, which are then labeled with percentage scores to depict the accuracy in the surveillance screen.
4. **BME688 Sensor:**
    - **Temperature/Humidity Measurement:** Should display temperature (in ℃) and humidity (in %)

- **Air Quality:** Gas resistance (in Ohms) & Air Quality indicator meter
- **Atmospheric pressure** (in hPa)

5. **Energy tracking:** Should generate real time power/energy consumption graphs for any load connected to the smart plug.
6. **Adding a Device:** Should be able to add a new device
7. **Pairing a Device:** Should be able to view existing connections with an option to pair within the client's environment.

3 Measurable Criteria

1. **Motion Sensor:** Detected any movement in front of the broad range of the sensor and updated the status of the sensor on the app simultaneously.
2. **Surveillance:** The face detection system successfully distinguished between authorized and unauthorized person and a real-time update for the same was on the app.
3. **Temperature and other indoor environment data:**
    - Displayed temperature in Celsius and and humidity in percentage
    - AQI meter with six different zones for indicating the air quality in a given room or area
    - Displayed atmospheric pressure in hPa
4. **Energy Tracking:** The energy screen on the app should show energy consumption and overall power usage graphs and current values of a particular outlet and the connected device and has ability to turn the connection "ON" or "OFF" through the mobile app.

5. **Device Pairing:** Enables users to discover and pair ESP32-based sensors connected to the same network using periodic backend check-ins. Available devices are displayed with relevant icons, and users can pair them with a single tap, after which the app persistently tracks their status for seamless integration.

4 Conclusion

4.1 Evaluation

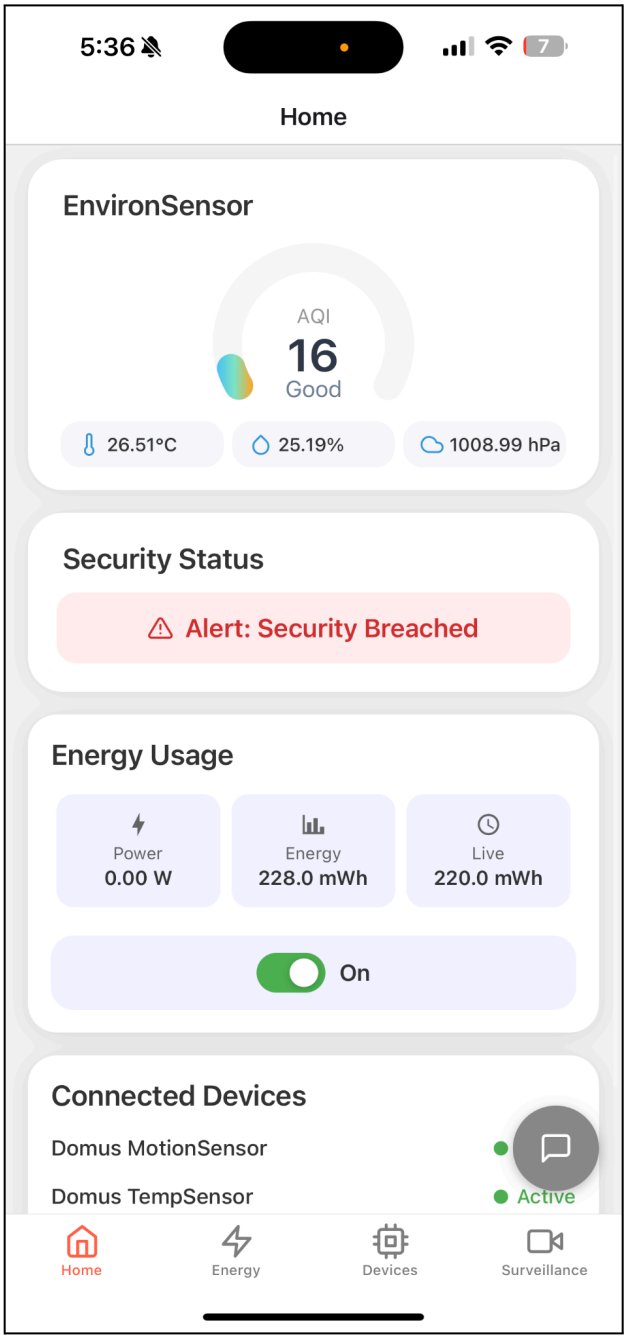
The final prototype's functionality was as expected. The motion sensor and BME688 both relayed real-time values to the React-Native iOS application. The camera module was able to distinguish between an authorized and unauthorized person and was able to display an alert to the mobile application in real-time. The smart plug also provided real-time energy consumption data to the mobile application and allowed for remote on/off capabilities.

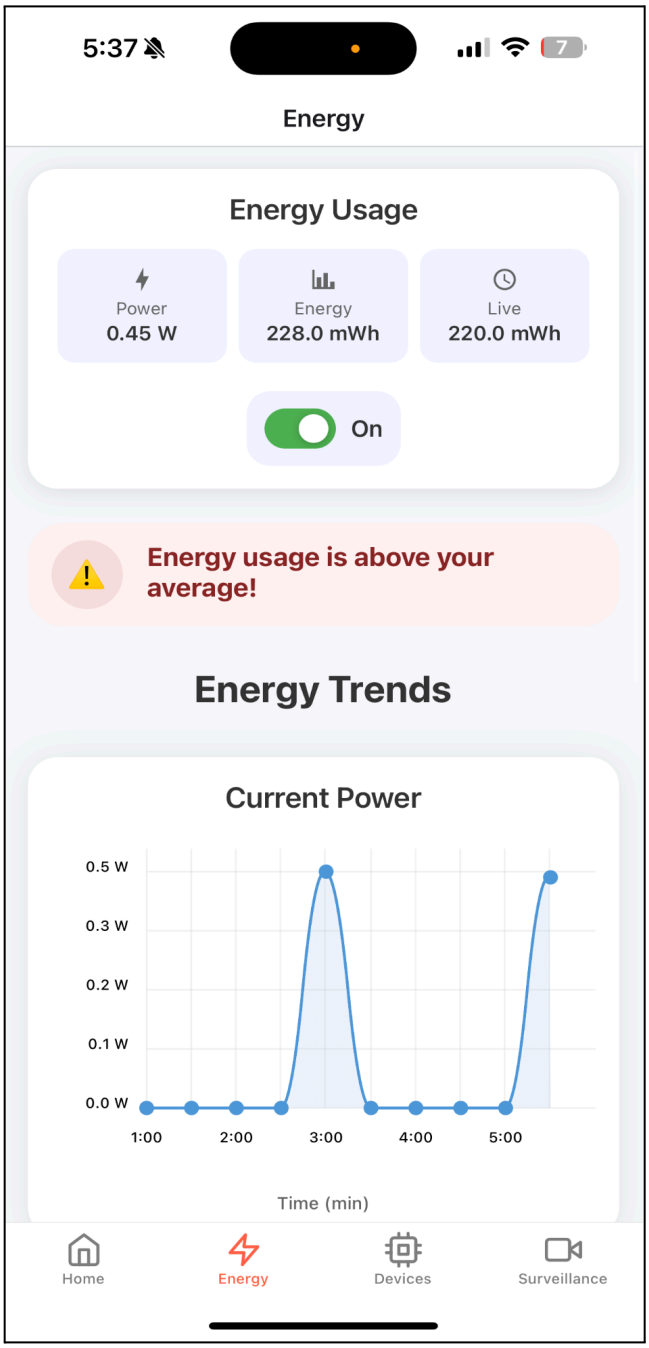
All the sensors connected to the Raspberry Pi 5 via the edge microcontrollers seamlessly as expected. The response from the sensors was fast and without hitches, as shown in the figures below.

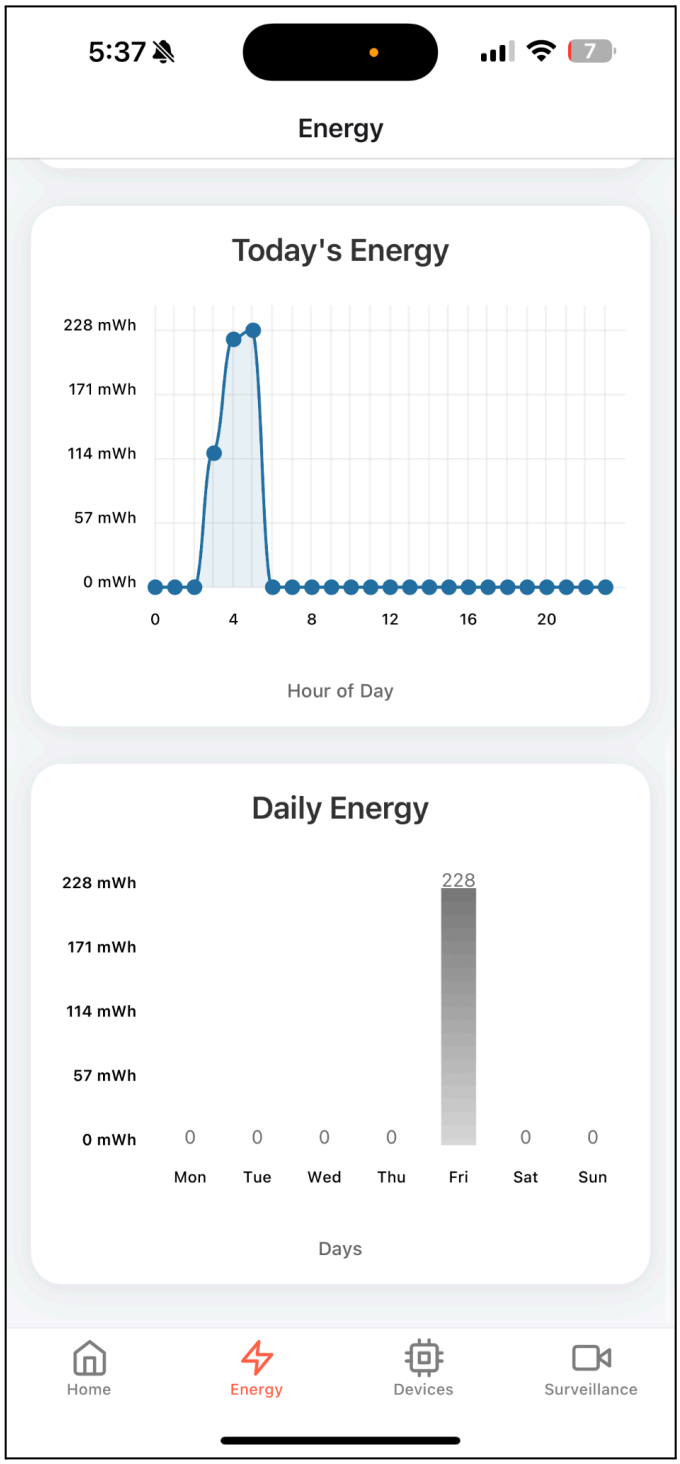
4.3 Scope of upgrades for ECE day

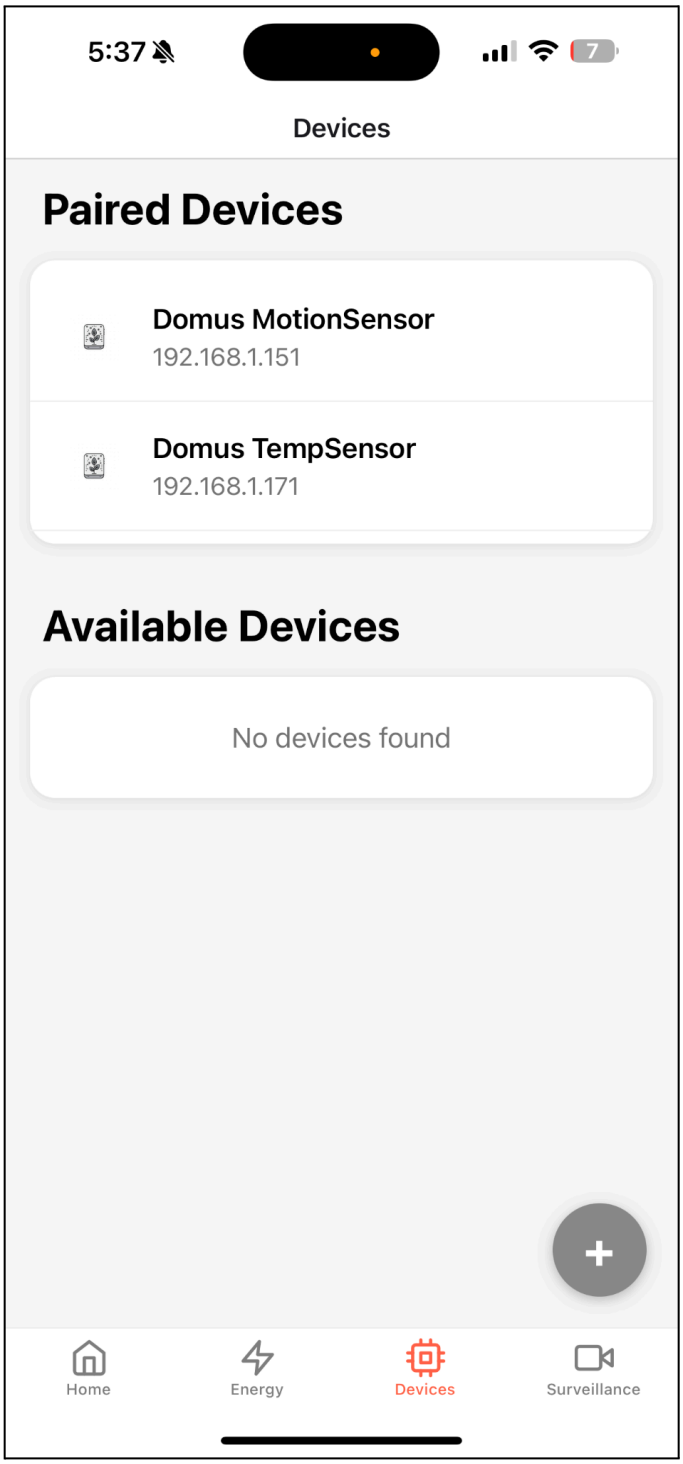
- Implement a "Wake Word" within the LLM functionality for an efficient interaction
- Train a more refined computer vision learning model for higher accuracy in object detection.

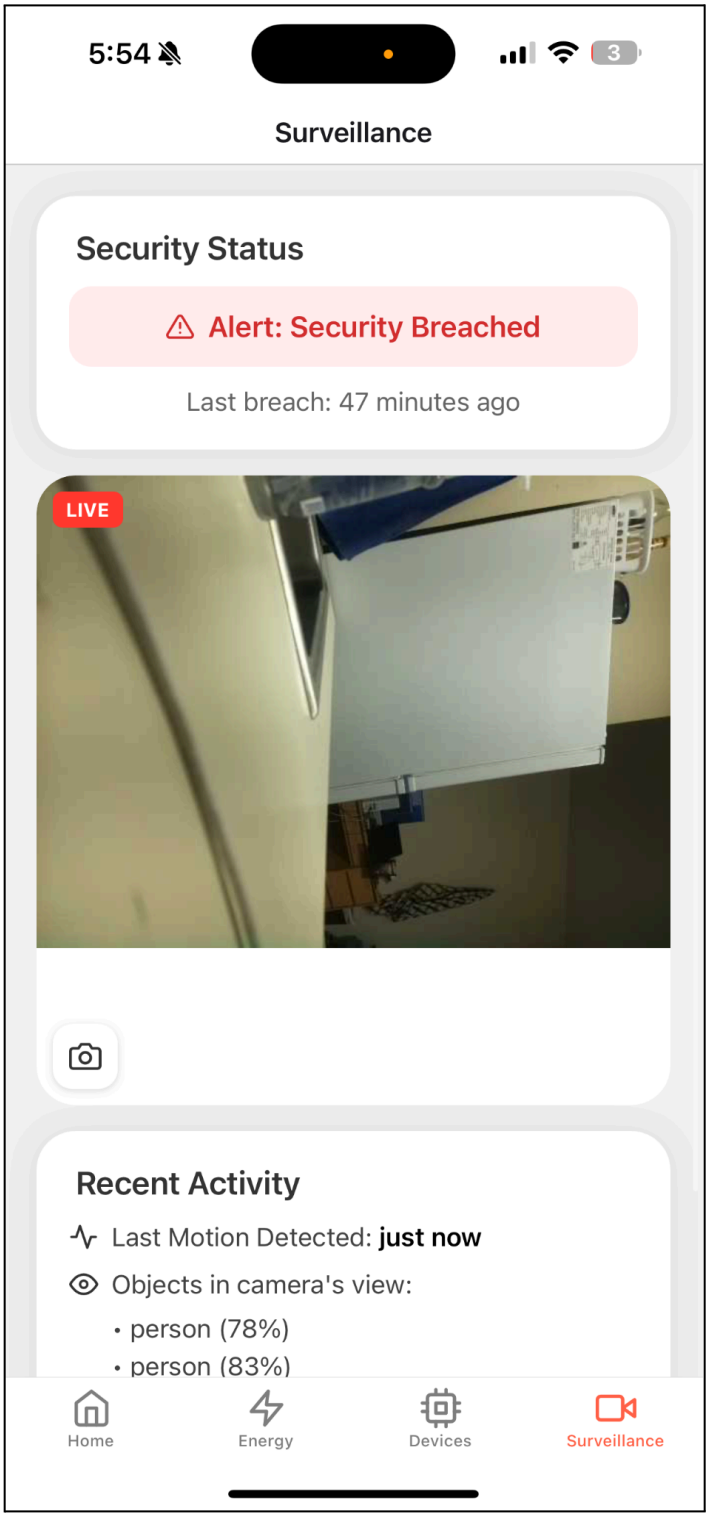
5 Appendix

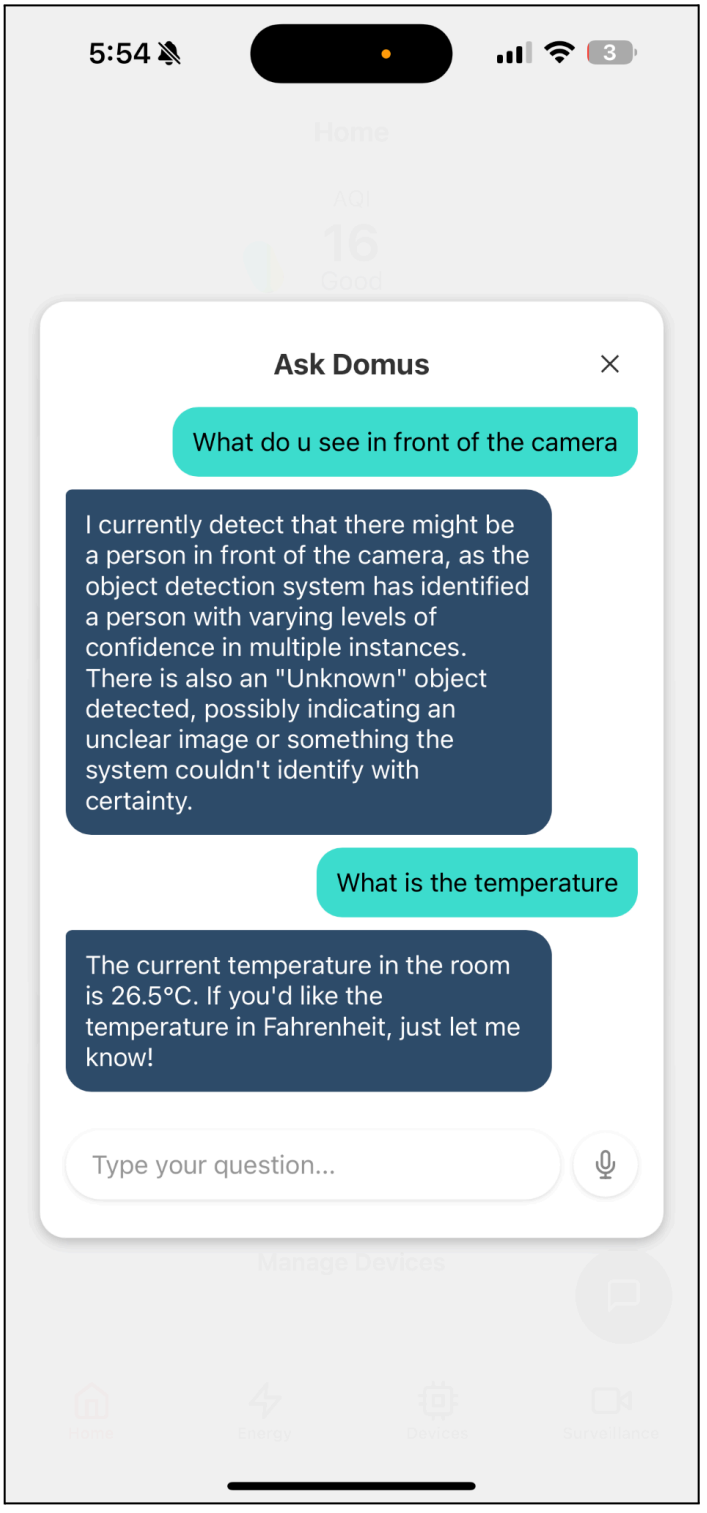

5:36
Home
EnvironSensor
AQI
16
Good
26.51°C
25.19%
1008.99 hPa
Security Status
Alert: Security Breached
Energy Usage
Power
0.00 W
Energy
228.0 mWh
Live
220.0 mWh
On
Connected Devices
Domus MotionSensor
Domus TempSensor
Active
Home
Energy
Devices
Surveillance


5:37
Energy
Energy Usage
Power
0.45 W
Energy
228.0 mWh
Live
220.0 mWh
On
Energy usage is above your average!
Energy Trends
Current Power
0.5 W
0.3 W
0.2 W
0.1 W
0.0 W
1:00
2:00
3:00
4:00
5:00
Time (min)
Home
Energy
Devices
Surveillance


5:37
Energy
Today's Energy
228 mWh
171 mWh
114 mWh
57 mWh
0 mWh
0
4
8
12
16
20
Hour of Day
Daily Energy
228 mWh
171 mWh
114 mWh
57 mWh
0 mWh
228
0
0
0
0
0
0
Mon
Tue
Wed
Thu
Fri
Sat
Sun
Days
Home
Energy
Devices
Surveillance


5:37
Devices
Paired Devices
Domus MotionSensor
192.168.1.151
Domus TempSensor
192.168.1.171
Available Devices
No devices found
Home
Energy
Devices
Surveillance


5:54
Surveillance
Security Status
Alert: Security Breached
Last breach: 47 minutes ago
LIVE
Recent Activity
Last Motion Detected: just now
Objects in camera's view:
• person (78%)
• person (83%)
Home
Energy
Devices
Surveillance


5:54
Ask Domus
What do u see in front of the camera
I currently detect that there might be a person in front of the camera, as the object detection system has identified a person with varying levels of confidence in multiple instances. There is also an "Unknown" object detected, possibly indicating an unclear image or something the system couldn't identify with certainty.
What is the temperature
The current temperature in the room is 26.5°C. If you'd like the temperature in Fahrenheit, just let me know!
Type your question...