Real-Time Environmental Monitoring using Raspberry Pi

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1 Introduction

Sensor-based embedded systems are transforming how we acquire and process environmental data. This experiment involves using a Raspberry Pi 4 for sensor data collection, transmission to a cloud platform, and secure storage using data masking techniques. The focus is on monitoring temperature, humidity, and air quality using a DHT11 sensor, with security measures for encrypted storage and correlation analysis.

2 Experiment Overview

The project includes the following tasks:

- Using a DHT11 sensor to measure temperature and humidity.
- Using an MQ135 sensor to measure air quality.
- Using an MCP3008 ADC to convert analog signals into digital data.
- Storing the data securely in an encrypted SQLite database.
- Analyzing correlations between temperature, humidity, and air quality.
- Implementing data security through encryption and masking.
- Sending an alert message when the temperature exceeds a predefined threshold.

3 Hardware and Connections

The experiment is conducted using a Raspberry Pi 4 along with sensors and interfacing modules. The detailed pin connections for each component are provided in the following tables.

3.1 DHT11 Sensor Connections

DHT11 Pin Function	Raspberry Pi Pin
VCC	Power (3.3V/5V) - Pin 1 (3.3V) or Pin 2 (5V)
DATA	Signal - GPIO4 (Pin 7)

GND	Ground - Pin 6 (GND)
NC (optional)	Not connected - Leave unconnected

3.2 MCP3008 ADC Connections

MCP3008 Pin Function	Raspberry Pi Pin
VDD Power (3.3V)	Pin 1 (3.3V)
VREF Reference Voltage (3.3V)	Pin 1 (3.3V)
AGND Analog Ground	Pin 6 (GND)
CLK Clock Signal	GPIO11 (Pin 23, SPI SCLK)
DOUT MISO (Data Out)	GPIO9 (Pin 21, SPI MISO)
DIN MOSI (Data In)	GPIO10 (Pin 19, SPI MOSI)
CS Chip Select	GPIO8 (Pin 24, SPI CE0)
DGND Digital Ground	Pin 6 (GND)

3.3 MQ-135 Air Quality Sensor Connections

MQ-135 Pin Function	Raspberry Pi Pin
VCC Power (5V)	Pin 2 (5V)
GND Ground	Pin 6 (GND)
AO Analog Output	MCP3008 CH0

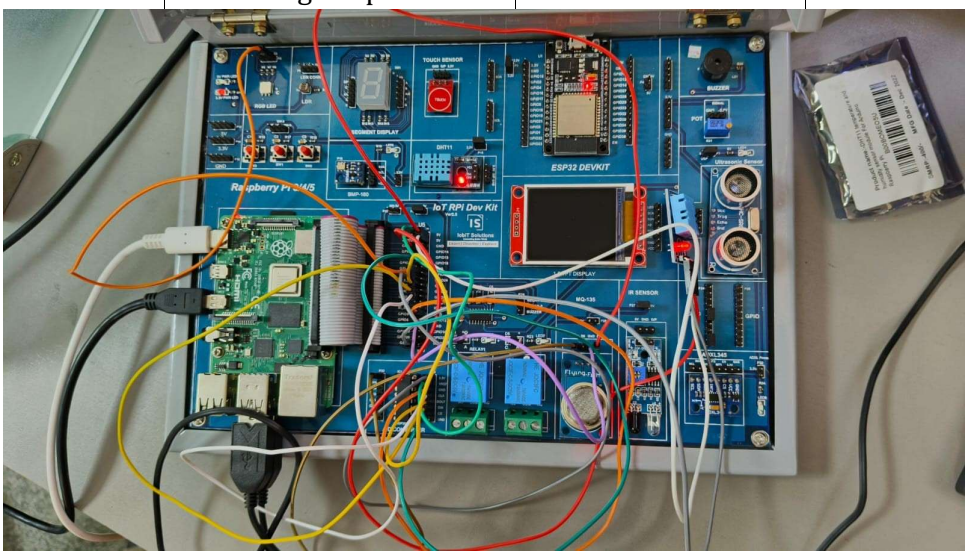

Figure 1: Circuit Diagram of the Real-Time Environmental Monitoring System

4 Data Collection and Storage

The script store-sensor-data.py is responsible for reading temperature, humidity, and air quality data from the DHT11 and MQ135 sensors, converting analog signals to digital using MCP3008, and securely storing the data in an encrypted SQLite database. The security implementation includes:

- **Encryption:** SQLCipher is used to encrypt stored sensor data.

- **Data Masking:** Sensitive data are masked before logging and transmission.
- **Authentication:** API keys are required to send data securely to ThingSpeak.
- **Error Handling:** Exception handling is used for database operations, sensor failures, and network requests.
- **Secure Storage:** Sensor readings are securely stored with timestamps.

5 Data Analysis and Correlation

The script corelationV.py retrieves encrypted data and performs correlation analysis using the Pearson correlation coefficient. Key findings include:

- Strong correlation between temperature and humidity.
- Variable correlation between air quality and temperature/humidity.
- Graphical analysis to visualize environmental trends over time.
- Matplotlib for visualization: Used Matplotlib to generate correlation graphs and time series plots.

6 Experiment Results

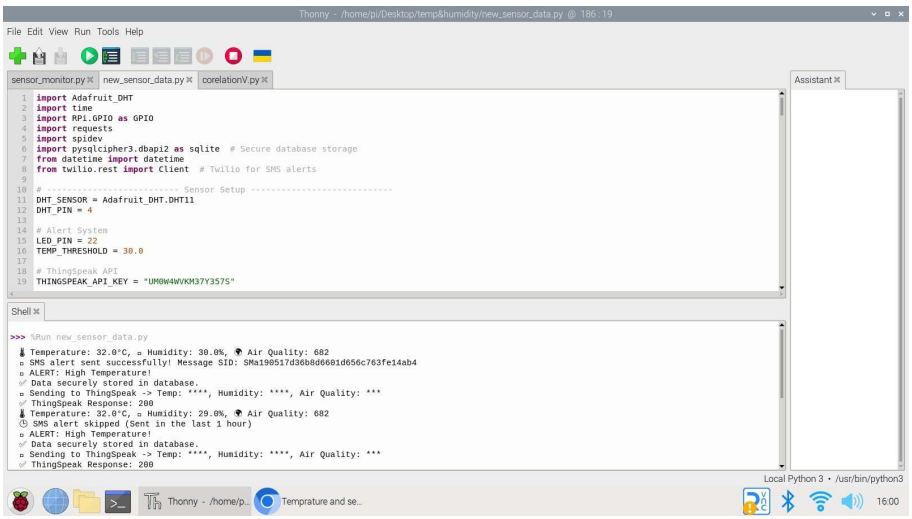

Figure 2: Encrypted Database Storage Verification

7 Security Implementation

Security is maintained through:

- **Database Encryption:** SQLCipher is used to store data securely.
- **Masked Transmission:** Only necessary data is shared with the cloud.
- **TLS Encryption:** Secure communication using MQTT with TLS.

8 Conclusion

This experiment successfully demonstrated the use of embedded systems for real-time environmental monitoring while ensuring secure data handling through encryption and masking. The correlation analysis provided insights into environmental conditions, paving the way for further applications in smart monitoring systems.

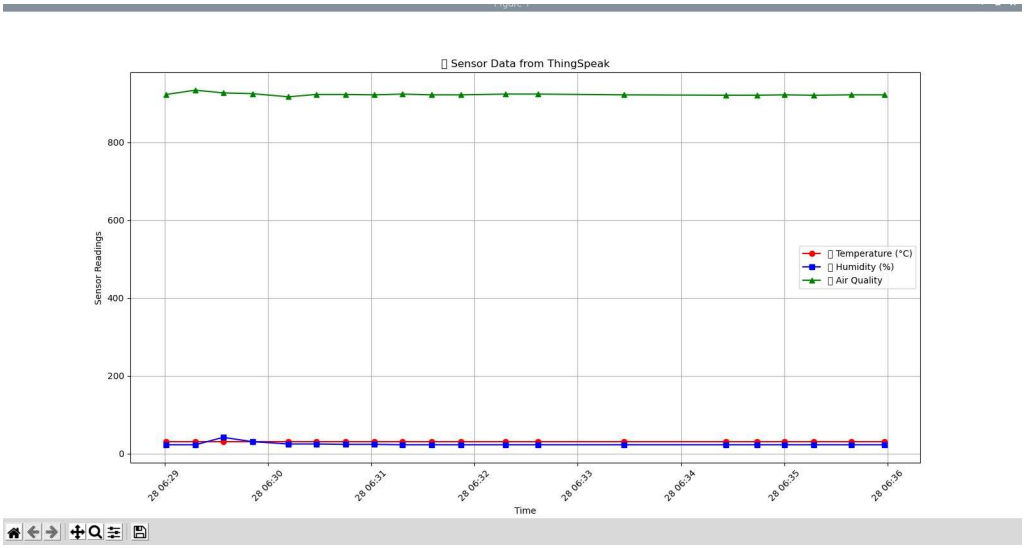

Figure 3: Sensor Data Visualization - Air Quality, Temperature, and Humidity

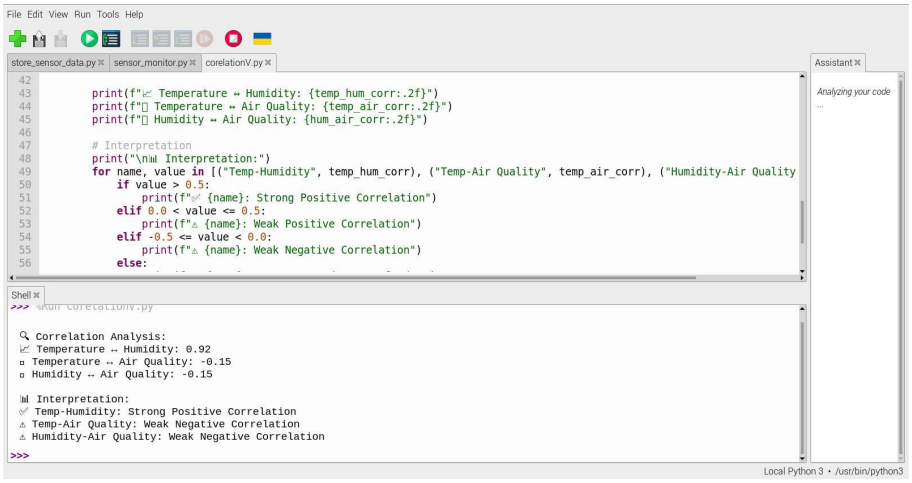

Figure 4: Data Analysis and Correlation

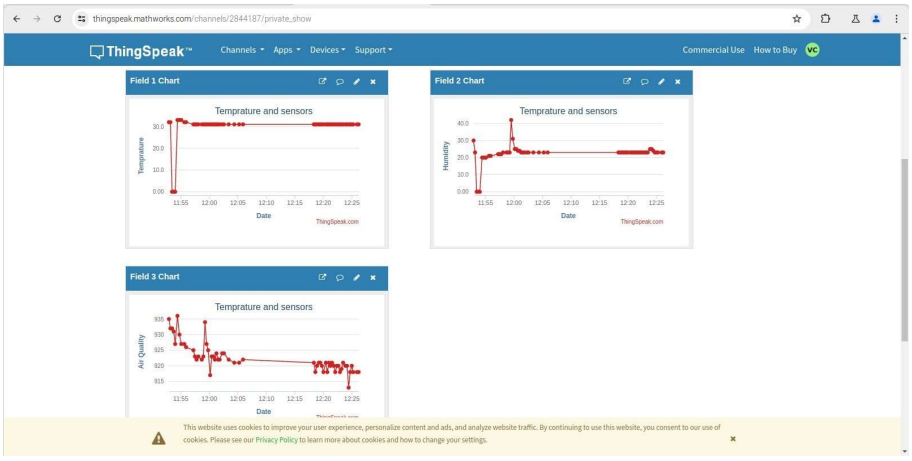

Figure 5: Secure Data Transmission Overview

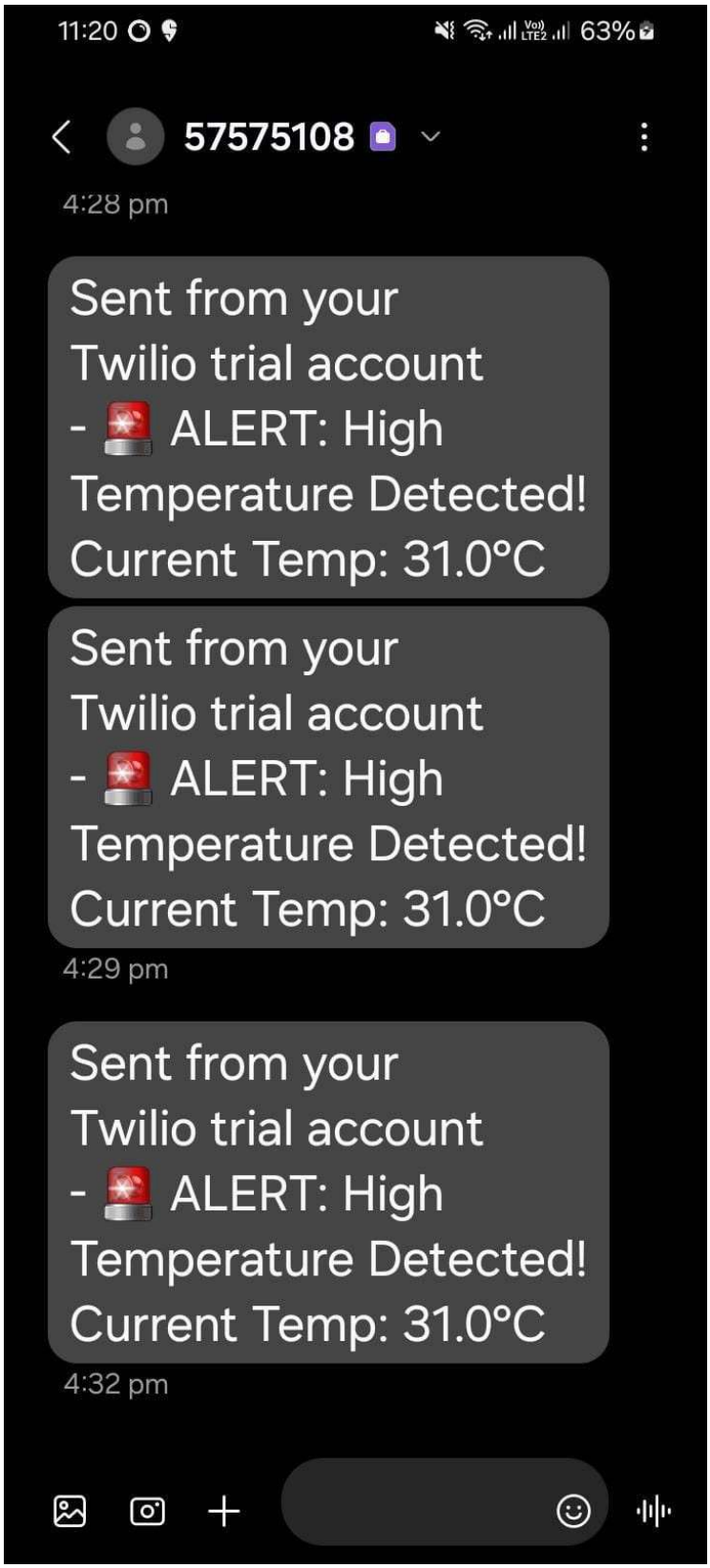

Figure 6: Message Received Alert for High Temperature