Development and Implementation of an IoT System using MQTT and Node-RED

Solar Project

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1. IoT System Design and Architecture

1.1 System Overview

The IoT monitoring system is designed to collect system data from various sensors, transmit the data to a central server using the MQTT protocol, and visualize the data using Node-RED and Node-RED dashboards. The system aims to provide real-time monitoring and analysis of system data, enabling proactive responses to temperature changes.

1.2 Components of the System

1.2.1 MQTT Protocol

- **Description**: MQTT (Message Queuing Telemetry Transport) is a lightweight messaging protocol designed for constrained devices and low-bandwidth, high-latency networks. It follows a publish/subscribe model.
- **Features**:
  - Lightweight and efficient
  - Supports Quality of Service (QoS) levels
  - Provides reliable communication
- **MQTT Broker**: The central component that handles message routing between publishers (sensors) and subscribers (Node-RED).

1.2.2 Node-RED

- **Description**: Node-RED is a flow-based development tool for visual programming, designed for wiring together hardware devices, APIs, and online services.
- **Capabilities**:
  - Real-time data processing
  - Integration with various protocols and services
  - Easy-to-use graphical interface
- **Usage**: Node-RED is used to design the data flow, process the incoming temperature data, and route it to the dashboard for visualization.

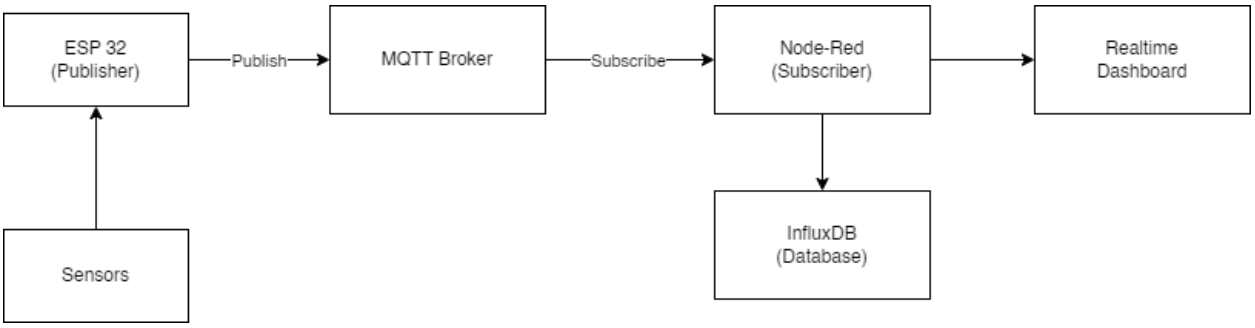
1.2.3 Node-RED Dashboards

- **Description**: Node-RED Dashboards are used to create web-based user interfaces to visualize the data processed by Node-RED.
- **Components**:
  - Graphs and charts to display temperature trends
  - Gauges to show real-time temperature values
  - Notifications for alerting abnormal temperature readings
- **Customization**: Dashboards can be customized to meet specific user requirements and provide intuitive data visualization.

1.3 System Architecture Diagram

The system architecture diagram illustrates the overall structure and data flow within the IoT temperature monitoring system. It includes the following components:

- Sensors: Collect data
- Microcontroller/Gateway: Interface between sensors and MQTT broker
- MQTT Broker: Manages message routing
- Node-RED: Processes data and manages dashboard
- Node-RED Dashboard: Visualizes data for end-users
- InfuxDB Database: Store data for later analyze



1.4 Data Flow and Communication

- **Data Collection**: Temperature sensors collect temperature data at regular intervals and send it to the microcontroller.
- **Data Transmission**: The microcontroller publishes the temperature data to the MQTT broker.
- **Data Routing**: The MQTT broker receives the data and routes it to the Node-RED server.
- **Data Processing**: Node-RED processes the incoming data, checks for anomalies, and prepares it for visualization.
- **Data Visualization**: The processed data is sent to the Node-RED dashboard, where it is visualized in real-time through graphs, gauges, and notifications.
- **Alerts and Notifications**: If the temperature readings exceed predefined thresholds, Node-RED triggers alerts and notifications on the dashboard.

2. Implementation

2.1 Hardware Setup

2.1.1 Selecting Temperature Sensors

The selection of temperature sensors is crucial for accurate data collection. Two types of sensors are used in this project: DS18B20 and DHT22. Each has its own advantages and specific use cases.

DS18B20 Digital Temperature Sensor:

- **Accuracy**: ±0.5°C ensures precise temperature readings.
- **Range**: Suitable for temperatures from -55°C to +125°C, covering most practical applications.
- **Communication Protocol**: The 1-Wire protocol allows for multiple sensors to be connected on a single data line, simplifying wiring and reducing the number of GPIO pins required.
- **Advantages**: High accuracy, simple integration, and robustness in various environments.

DHT22 Temperature and Humidity Sensor:

- **Accuracy**: Temperature accuracy of ±0.5°C and humidity accuracy of ±2-5% RH.
- **Range**: Temperature range from -40°C to +80°C and humidity range from 0-100% RH.
- **Communication Protocol**: Uses a single digital pin for communication, making it easy to connect to microcontrollers.
- **Advantages**: Provides both temperature and humidity readings, making it versatile for applications requiring both parameters.

These sensors are chosen to provide a comprehensive monitoring solution, with the DS18B20 focusing on precise temperature measurement and the DHT22 offering additional humidity data.

2.1.2 Sensor Calibration

Calibration ensures that the temperature readings are accurate and reliable. The process involves:

- **Baseline Measurement**: Measuring the temperature in a controlled environment using a calibrated reference thermometer.
- **Sensor Adjustment**: Adjusting the sensor readings in the code to match the reference thermometer readings.
- **Repeated Tests**: Performing multiple measurements at different temperatures to ensure consistent accuracy across the sensor's range.

2.1.3 Connectivity Setup

Establishing reliable connectivity between the sensors and the microcontroller is essential for real-time data transmission. The setup involves:

- **Wiring**: Connecting the DS18B20 and DHT22 sensors to the microcontroller, ensuring proper data, power, and ground connections.

- **Power Supply**: Providing a stable power source to the sensors and microcontroller.
- **Communication Protocols**: Configuring the microcontroller to read data from the sensors using the 1-Wire protocol and then publishing this data to the MQTT broker.

2.2 Software Development

2.2.1 MQTT Broker Configuration

The MQTT broker is the central component that manages message routing between publishers (sensors) and subscribers (Node-RED). The configuration steps include:

- **Broker Selection**: Choosing an MQTT broker, such as Mosquitto, which is lightweight and open-source.
- **Installation**: Setting up the MQTT broker on a server or a cloud platform.
- **Security Configuration**: Implementing security measures such as SSL/TLS encryption and user authentication to protect data transmission.
- **Topic Structure**: Designing a topic structure for organizing the data, for example, `home/temperature/sensor1`.

2.2.2 Node-RED Flow Design

Node-RED is used to design the data flow, process incoming temperature data, and prepare it for visualization. The design process includes:

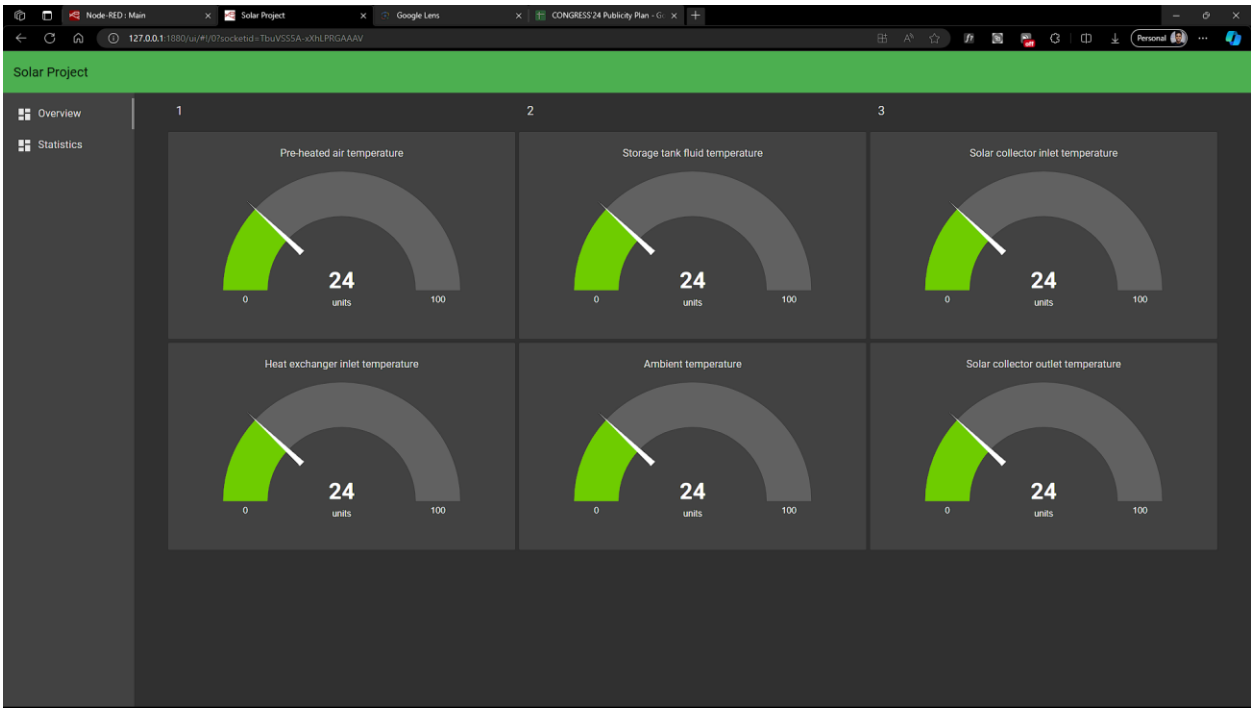
- **Node Configuration**: Adding and configuring nodes for MQTT input, data processing, and output.
- **Flow Design**: Creating a flow that subscribes to the MQTT topics, processes the temperature data, and routes it to the dashboard.
- **Error Handling**: Implementing nodes to handle errors and ensure reliable data processing.

2.2.3 Dashboard Creation

Node-RED dashboards provide a user-friendly interface for visualizing the temperature data. The creation process includes:

- **Layout Design**: Designing a dashboard layout that includes charts, gauges, and tables to display real-time and historical temperature data.
- **Widget Configuration**: Adding and configuring widgets to display the temperature readings, trends, and alerts.
- **User Interaction**: Implementing interactive elements such as buttons and sliders for user control and customization.


System HMI
Date/Time
Solar Radience
Flow Rate
Air Flow Fan - Input
Heating element active time


Node-RED : Main
Solar Project
Google Lens
CONGRESS'24 Publicity Plan - G
127.0.0.1:1880/ui/#!/0?socketid=TbuVS5SA-xXhLPRGAAAV
Personal
Solar Project
Overview
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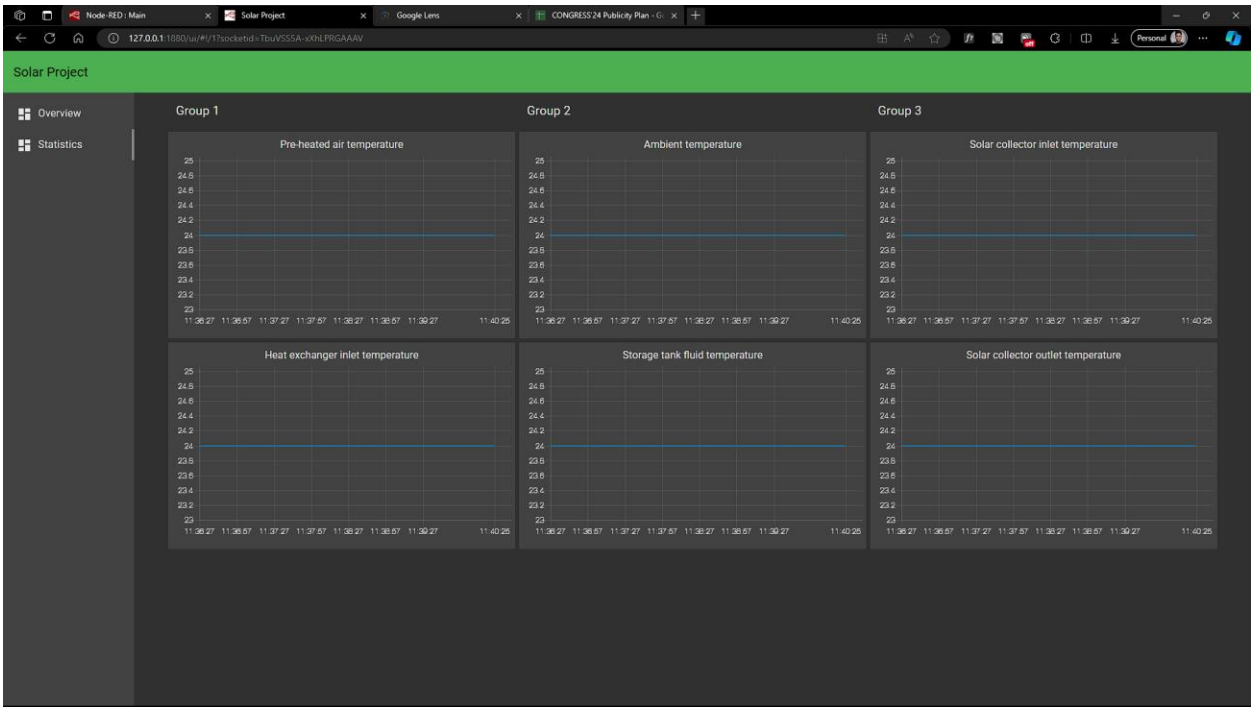

2.3 Integrating Hardware and Software

The final step is to integrate the hardware components with the software to create a fully functional IoT temperature monitoring system. This involves:

- **Testing Connectivity**: Ensuring that the sensors are correctly connected and communicating with the microcontroller.
- **Data Transmission**: Verifying that the microcontroller is publishing data to the MQTT broker and that Node-RED is subscribing to and processing this data correctly.
- **Dashboard Validation**: Checking that the data is accurately displayed on the Node-RED dashboard and that all widgets are functioning as intended.
- **System Optimization**: Fine-tuning the system for performance, including optimizing data transmission rates, processing times, and dashboard refresh rates.
- **Final Testing**: Conducting comprehensive tests to ensure the system operates reliably under various conditions and scenarios.

3. Budget

Component	**Model**
Microcontroller	ESP32
Thermo sensors	DHT11
	DS18B20
Flow Meter	YF-S201
Water Pump	
DC – Motor Controller	1803BK
AC – Motor Controller	
Voltage regulator – 5V	LM2596
Power Supply - 12V	
Power Supply – 3V	
Temperature Controller	XH-W3001
Wire(3)	
Soldering Lead	
Pin Headers	Female to male
Dot Board	Large