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Design of ESP8266 Smart Home Using MQTT and Node-RED

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***Abstract*—Developments in Internet of Things (IoT) have enabled innovations in smart home and industrial automation, providing possibilities for devices in homes to be monitored and controlled remotely. Such solutions have resulted in energy efficiency and cost savings, as appliances are monitored and controlled by small, resource constrained embedded devices. The paper presents a design of an ESP8266 NodeMCU smart home solution, using Message Queuing Telemetry Transport (MQTT) and Node-RED. The smart home solution design utilises an MQTT mosquito broker on raspberry Pi 3B+, a single board computer development board. A DHT 22 sensor is interfaced with the ESP8266 micro-controller to collect sensor data for temperature and humidity, with the raspberry Pi performing functions of MQTT broker to relay sensor data information to a Node-RED dashboard.**

***Index Terms*—IoT, Smart Home, ESP8266, MQTT, Node-RED, DHT 22, Remote Monitoring.**

I. Introduction

Across the globe, there is an increasing demand for efficient energy utilization [1]. In addition, increased human mobility for work or other activities has resulted in increased demand for remote monitoring of technology and conditions in the home. Example areas of interest include security and electronic device monitoring and control [1,2].

To address such demands there are propositions for smart home solutions that enable remote monitoring and control of home devices and conditions. Waleed [2] defines smart homes as "living environments equipped with advanced intelligent technologies that manipulate and respond in step with the wants of the house residents".

Smart home automation typically consists of distributed sensors and actuators and a central microcontroller [2].A key enabler for smart home solutions is the rapid development of the Internet of Things (IoT), mobile internet technology, cloud computing, and sensor technology [2,3]. It's also worthwhile noting that smart solutions are increasingly relevant in automating the monitoring and control of industrial machinery [4]. However, despite notable achievements, the adoption and utilisation of smart home solutions is faced with several challenges ranging from being expensive to purchase, security and privacy vulnerabilities and the proprietary nature of leading solutions [5].

This paper presents a design of an ESP8266 NodeMCU smart home solution, using Message Queuing Telemetry Transport(MQTT) and Node-RED. The smart home solution design utilizes an MQTT mosquito broker on raspberry Pi 3B+, a single board computer development board.

II. Existing Literature

The basic concept of a smart home system is to control and monitor household appliances remotely. In [3], the authors present a laptop-based mostly wireless home automation system. The projected system consists of an associate automatic speech recognition system that identifies spoken words and converts them into text commands in MATLAB.The text commands are then transmitted to a micro-controller via a powerless RF ZigBee-based device system. The microcontroller controls the home electrical appliances via its corresponding relays. The system uses low latency ZigBee modules that are vulnerable to interference, hence signal weakening.

In [4], the authors present architectures for home automation and planned a unique home automation architecture giving room to all or any of the new IoT protocols such as CoaAP, Zigbee, and Bluetooth but did not involve lightweight low bandwidth communication protocols like MQTT.

In [5], the authors present a solution meant to perform home automation through SMS. A GSM network is deployed and a devices area unit is bridged employing a micro-controller and GSM module. Additionally, the solution presented focuses on security aspects within the networking and proposes a secure, reliable, and adaptable home automation system. A

key downside to the proposed solution is that it requires base stations with low latency and high bandwidth.

III. Objectives and Contribution

The main objective of the study was to design and implement an ESP8266 smart home solution using MQTT with Node-RED, for remote monitoring of any appliance in a smart home. A followup-up objective was to send sensor data of temperature and the humidity level of a smart home to a Node-Red dashboard, as a test case

IV. Proposed System Architecture

Figure 1. display's the proposed architectural system for the Nodemcu ESP8266 smart home with MQTT and Node-RED system.The smart home automation application would be running on the Raspberry Pi MQTT broker controlling various devices in real time. This architecture presents merits of being low-cost,affordable, low resource needs and open source.

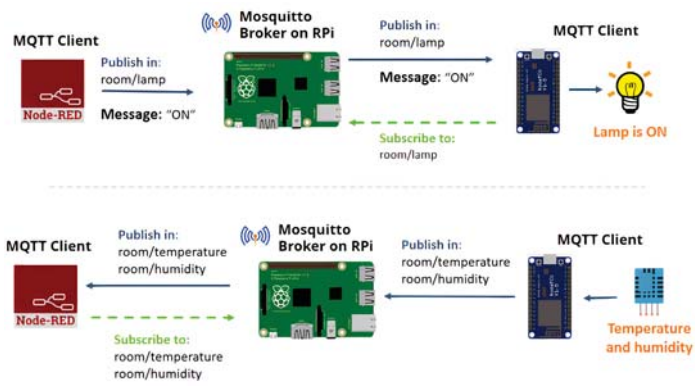

Fig. 1. Overview of a System Architecture [5]

V. System Design

The proposed system design of the ESP8266 smart home using mqtt and node-red was implemented with hardware not limited to NodeMCU ESP8266 microcontroller,temperature and humidity sensor DHT22, Raspberry Pi 3B+ , and LED.

A. NodeMCU ESP8266

NodeMCU ESP8266 is an open-source Espressif microcontroller board based on Lua firmware.Its can be used for different IoT applications based on a few script lines [7]. The firmware runs on the ESP8266 Wi-Fi SoC from Espressif System. NodeMCU ESP8266 is a low-cost Wi-Fi module which has a TCP/IP.ESP8266 has ESP-12E module containing ESP8266 chip with Tensilica Xtensa 32-bit LX106 RISC microprocessor [6,7]. The board has 128 KB of RAM and 4MB of Flash memory for data storage of data and programs [8]. It has high processing power which makes it ideal cross-cutting open edge IoT projects.

B. DHT 22

The DHT 22 is a digital sensor that measures temperature and relative humidity [9]. DHT 22 is an encompassed A-D converter chip that does signal conversion from analog and remits out a digital signal with the temperature and humidity.The DHT 22 has a dedicated NTC which measures temperature interfaced with an 8-bit microcontroller which outputs the values of temperature and humidity as serial data comes along with the DHT 22 sensor [9]. This makes this sensor to be easy to use with any microcontroller,including the NodeMCU ESP8266 for smart home applications.

C. Raspberry Pie 3B+

Raspberry Pi is a low-cost mini-computer [10]. It supports several programming languages like Scratch,Python, java and many others. The processor has 700 MHz to 1.4 GHz frequency ranges in Pi 3 model B+. The RAM memory varies from 256 MB to 1 GB RAM. Raspberry Pi 3B+ contains 64-bit quad core ARM cortex A53 processor with a clock speed 1.4 GHz [9]. The raspberry pi in this system is running the mosquito MQTT broker and the deployement of the Node-RED.

D. Light Emmiting Diode LED

The light-emitting diode (LED),presents a diode that emits light [11]. Diodes are electronic components that have polarity, meaning they allow current to flow in only one direction, from positive to negative [11]. LEDs, like all diodes, have a positive terminal known as an anode, and a negative terminal known as a cathode.The LED is acting as a lamp in the proposed system of ESP8266 smart home.

VI. System Software

A. Arduino IDE

The Arduino (IDE) is a software which is open-source, and it helps in code scripting and uploads to the microcontroller boards [9]. It runs on Windows, Linux and Mac OS X. The IDE communicates with the Nodemcu ESP8266 microcontroller and helps to view sensor data in serial monitor.

B. MQTT Broker

MQTT is a simple messaging protocol which is an acronym for Message Queue Telemetry Transport, designed for constrained devices with low-bandwidth[13].It is a lightweight publish and subscribe system which publishes and subscribes to messages as clients.The Mosquito MQTT broker is responsible for receiving all messages, filtering the messages, deciding clients interested in the message and then publishing the message to all subscribed clients [12]. In the smart home system design the Mosquito MQTT broker was installed on the raspberry pi 3B+.

C. Node-RED

Node-RED is an JavaScript-based development environment making use of Node.js [14].It is used for IoT system development by wiring together APIs, hardware devices and online services and was developed by IBM [15]. The Node-Red dashboard presents the user interface for the system with control button, a gauge and a chart.

VII. Technology Description

The circuit schematic diagram display's step by step how to interface the DHT22 with the NodeMCU ESP8266 microcontroller. The data pin of the DHT22 is connected to GPIO pin 5 (D1) of the Nodemcu ESP8266. The VCC and GND of the DHT 22 are connected to the 3V3 supply voltage and GND respectively.The LED receives a signal from GPIO pin 4 (D2) of the ESP8266 board.Finally, the arduino sketch is uploaded into the Nodemcu ESP8266 microcontroller using the Arduino IDE. Figure 2. shows the circuit schematic diagram which was used in the implementation of the prototype.

A. Circuit Schematic Diagram

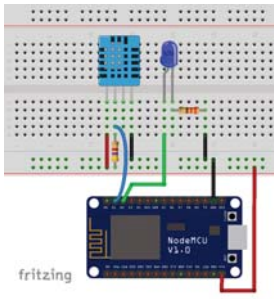

Fig. 2. Circuit Schematic Diagram [5]

VIII. Result and Output

A. Implemented Prototype

Figure 3. display's the implemented prototype of the ESP8266 smart Home of MQTT and Node-RED where DHT 22 temperature and humidity sensor, LED are interfaced with the NodeMCU ESP8266 to get the desired experimental result.

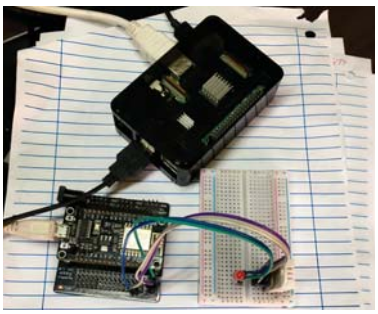

Fig. 3. Implemented Prototype

B. Node-RED flows

Figure 4. show's the Node-RED flows wiring which enables the dashboard visualization and the control of outputs as well as publishing the sensor data to the web dashboard.

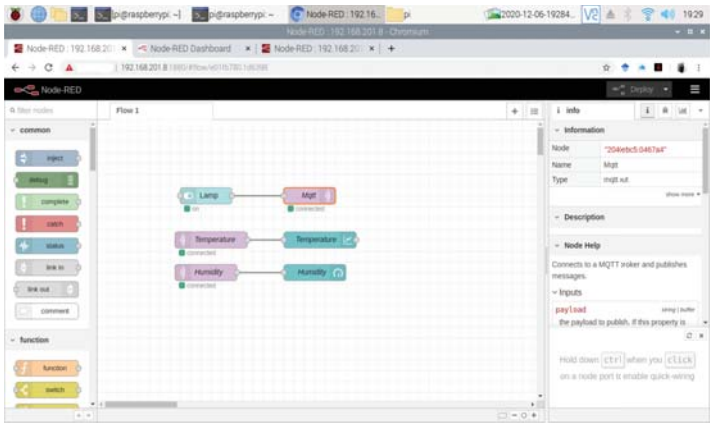

Fig. 4. Node-RED flows

C. Results

Figure 5. shows the sensed data from the NodeMCU ESP8266 sensor node displayed on a serial monitor with the IP adresse connected and the notification of connection to mosquitto MQTT broker.The messages which the ESP8266 is publishing and receiving are outlined hence outlining the real time events of the smart home in real time with low latency.

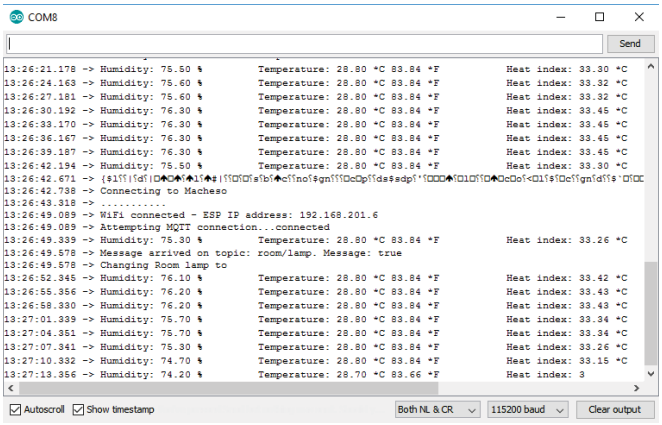

Fig. 5. Sensor Data on Serial Monitor

D. Web Dashboard

The NodeMCU ESP8266 is publishing humidity and temperature readings every 10 seconds on the room/humidity and room/temperature topics. The Node-RED dashboard that supports MQTT can be used to receive this sensor data if it subscribes to the above topics. Its has also control options which can turn appliances on and off through the topic room/lamp. Figure 6. shows the web dashboard of Node-RED displaying sensor data and control inputs.

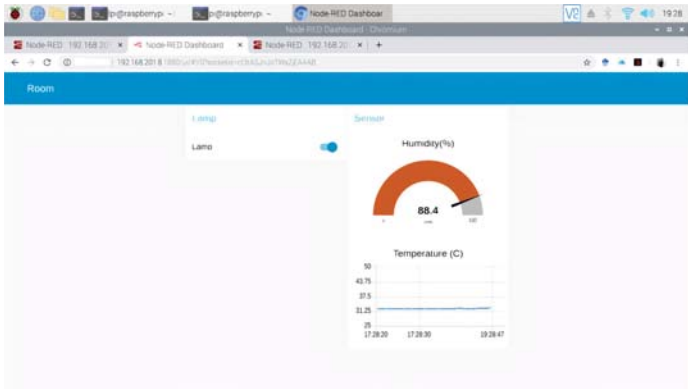

Fig. 6. Web Dashboard

IX. Conclusion and Future Scope

This paper presents the design of a smart home solutions using on ESP8266 microcontroller with MQTT and Node-RED is presented. The smart home controls the NodeMCU ESP8266 outputs for home automation and displays sensor data on a Node-RED dashboard from the sensor node made by interfacing NodeMCU ESP8266 and DHT 22 with the LED. In the design, Node-RED software running on Raspberry Pi 3B+ and the MQTT communication protocol facilitate communication between the NodeMCU ESP8266 and the node-RED software.

The future works of the proposed smart home system presented will involve interfacing more sensors to collect sensor data for other environmental parameters in a home setting and interfacing alot more appliances to the sensor node to nearly the entire home setting.

Acknowledgment

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