

Design and Implementation of Smart Home through Message Queuing Telemetry Transfer (MQTT) Protocol

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ABSTRACT

In the last few years, the use of Internet of Things (IoT) technologies has gained importance in several application areas, especially in the smart home domain.

This paper will focus on the design and the implementation of a smart home prototype by acquiring real-time data inputs and transmitted through the Message Queue Telemetry Transfer (MQTT) protocol. The implemented system has been tested successfully through a smartphone application. The data are published with the support of a broker, which is in charge of transferring the messages to the targeted clients depending on the topic selection (light, temperature, humidity, gas). Finally, the functionality tests of MQTT have been performed and the observed data ensured that the system is working efficiently.

KEYWORDS

Internet of Things, Smart Home, Home automation, Message Queue Telemetry Transfer, Android.

1 Introduction

The IoT can be incorporated into the smart environment, enhancing the capabilities of the objects and allowing the consumer to remotely control the environment [1]. Today, everywhere, smartphones are available with different functionalities. This smartphone can connect with any other device with GSM and WIFI technology inside the home. For example, when we are away from home without being aware that a device such as a ventilator or a light tube is on, with the smartphone, we can turn off the power for that specific device. With advances in electronics and computer science, all devices can be monitored through microcontrollers and internet connections.

The smart home domain covers a wide diversity of technologies, applications, and services where all familiar everyday objects in people's lives are "smart". In this respect, to enhance the quality of life of individuals, the smart objects available in the home can be connected by implementing solutions that are already being offered for the Internet of Things.

Moreover, to allow communication between different devices e.g., multiple sensors, actuators, microphones, cameras, smart appliances, etc. and with the world outside, the Message Queue Telemetry Transfer protocol is used as a home automation middleware. There are a number of alternative protocols to MQTT but MQTT is the only protocol, which is built for IoT and it is used to provide new and revolutionary performance.

The main contribution of this paper is to remotely control home appliances uses Wi-Fi and Message Queuing Telemetry Transport (MQTT) protocol. In this way, users can control home devices by using smartphones.

The remainder of this paper is organized as follows. Section 2 introduces the basic concepts like the home automation, IoT, and Message Queuing Telemetry Transport (MQTT) protocol. Section 3 presents related work. Section 4 gives an overview of the prototype. Section 5 describes the motivating scenario and our main contributions. The last section gives a brief conclusion.

2 Background

This section presents the mains concepts related to our research.

2.1 The Internet of Things (IoT)

The Internet of Things (IoT) is defined as a network of connected physical devices connected to the internet. Organizations can mix physical detection with data analysis to make significant insights. IoT platforms provide solutions in smart cities, smart grids, smart homes, and networked vehicles that could bring significant qualitative enhancement to people's lives. The IoT can also be an enabler of economic growth by increasing productivity, reducing costs, and improving lives [2].

The IoT encompasses a diverse set of technologies such as wireless and wire-based sensor networks and controllers, smartphone devices, and advanced communication protocols over the internet. The main idea of IoT is to connect many heterogeneous devices via the Internet so that they operate intelligently, efficiently, and securely [3].

2.2 Home Automation

Several definitions of home automation have been proposed, and with the progress of technologies, these definitions are getting improved every day.

Home automation covers all the electronic elements, building physics, middleware, computer science, and telecommunications that are used in buildings, which are more or less "interoperable" and allow the centralized control of the different systems and subsystems of the house and the company (heating, shutters, garage door, entrance gate, electrical outlets, etc.) [4].

The Internet could be used for home automation to make several decisions such as reduce energy consumption, ensure an optimal indoor climate, provide residents with a means of security, remote observation, and management to guarantee safety even when they are away, etc. Internet-based home automation systems are one of the most popular systems in the global market [5].

2.3 Message Queuing Telemetry Transport

Message Queuing Telemetry Transport (MQTT) is a lightweight transport protocol for machine-to-machine communication. It operates over TCP and delivers messages from the node to the server.

MQTT operates in a topic-based publish and subscribe mode. The pub/sub (Publisher/Subscriber) MQTT protocol is used to communicate and send messages between machines that can connect to a network. Its publication and subscription are organized based on the idea of "topic" and all packets are published through the broker [6].

The publish-subscribe mode involves three entities: publisher, subscriber, and a broker. This means that when a client publishes a message on a particular topic, all clients that have subscribed to the same topic can receive that message. All machines, called "clients", communicate through a central server called "broker". Clients such as sensors, mobiles, etc. can be publishers, subscribers, or both. All clients must uniquely identify themselves when connecting to the broker.

For example, a temperature sensor that detects temperature data and publishes what it has on the Hive-MQ broker, which is a type of free online broker. Figure 1 shows the MQTT Publish/Subscribe architecture [7].

On the client-side, two main devices are a laptop and a smartphone, and they have subscribed to a temperature topic so that the temperature data can be sent to both devices through the broker. In this way, the server can publish data while the client can receive it [7].

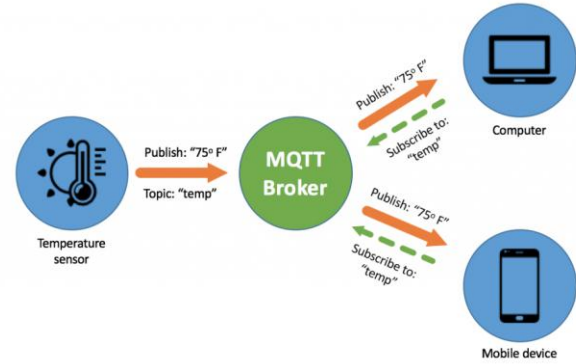


Figure 1. MQTT Publish/Subscribe architecture [7]

3 Related Works

Numerous research works have dealt with this subject. For example, in [8], the authors discussed the MQTT protocol and how communication can be established between clients, then they proposed a novel home automation architecture using this protocol. In [9], the authors proposed a security system for the indoor and outdoor of the house, integrating many devices such as biometric fingerprint scanners and other sensing tools to ensure the system prevents unauthorized access. The proposed work in [10] contributes to implement an IoT-based weather monitoring system to decouple the complexity and load among data-retrievers, database-stores, and visualized-data viewers. The individual sensor sends the data string to the MQTT server. Then the data-subscriber is set by using Node-Red technology to translate those data-strings into SQL strings and send those to database serve. In [11] a prototype is designed to perform home automation for disabled people using an Android App to control electrical appliances and uses cell phones through global mobile communication (GSM) technology and wi-fi technology also the SMS technology is used to control household appliances for long-distance. The work in [12] paper describes an Internet of Things-oriented architecture for the Smart Home, based on the long-range and low-power technology LoRa. In which the devices communicate with each other and the outside world using the Message Queue Telemetry Transfer protocol.

4 Implementation and Prototyping

To ensure the best functioning of our prototype, we include the following elements:

- A WIFI communication module: The ESP8266 is capable of either hosting an application or offloading all Wi-Fi networking functions from another application processor [7]. The ESP8266 has embedded processing and storage capabilities to integrate the chip with sensors or with the application of certain tools.

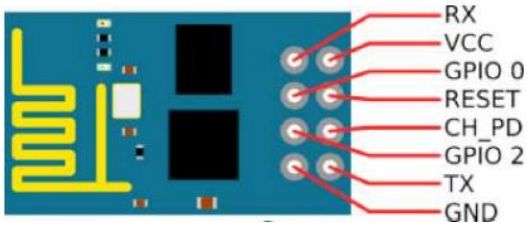


Figure 2. ESP8266 Wi-Fi Module

- A control board: After a preliminary study, we choose the Arduino Mega 2560 board (Figure 3), which meets our needs and offers a good price-quality ratio. The Arduino Mega 2560 board is a microcontroller board based on an ATmega2560. To use this microcontroller we need to connect it to a computer with a USB cable. Arduino Mega 2560 development board is shown in Fig. 14.



Figure 3. Arduino Mega 2560 board

- Ventilator 5V: we use it to generate a greater airflow, also ensuring additional cooling either in the case of gas detection or in case of an increase in temperature. The cooling capacity of heat sinks especially increases in this way.



Figure 4. Ventilator 5V

- Sensors: In this work, we use three sensors. First, the DHT11 sensor allows the measurement of temperature and humidity. The key advantages of the DHT11 sensor are the excellent quality, anti-interference ability, fast response, and high-cost performance [7].

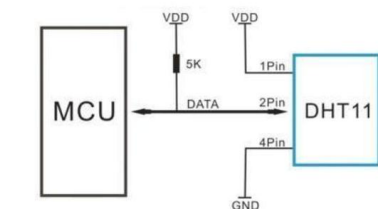
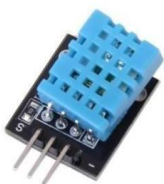


Figure 5. DHT11 sensor

Second, the MQ-2 sensor allows detecting gas or smoke at concentrations of 300 ppm to 10000 ppm. After calibration, the MQ-2 can detect different gases such as LPG i-butane, propane, methane, alcohol, hydrogen, and smoke. It is designed for indoor use at room temperature.



Figure 6. MQ-2 sensor

Third, the HC-SR04 sensor uses ultrasound to determine the distance to an object. Regardless of the light intensity, temperature, or type of material, the sensor will easily detect if there is an obstacle in front of it.



Figure 7. HC-SR04 sensor

-Buzzer: A buzzer is a kind of loudspeaker but of low power which will emit a sound according to the depending on the frequency and amplitude of vibration. It allows to play notes and to recreate simple melodies



Figure 8. A buzzer

We also use, on one hand, the open-source Arduino Software (IDE). The environment is written in C and based on processing and other open-source software. This software can be used with any Arduino board. On the other hand, we use App Inventor for Android which is an application developed by Google. It is currently maintained by the Massachusetts Institute of Technology (MIT). It simplifies the development applications under Android and makes it accessible even for novices and those who are not familiar with programming languages.

Figure 9 represents the request path and Figure 10 shows the functioning of the sensors linked to the Arduino Mega board.

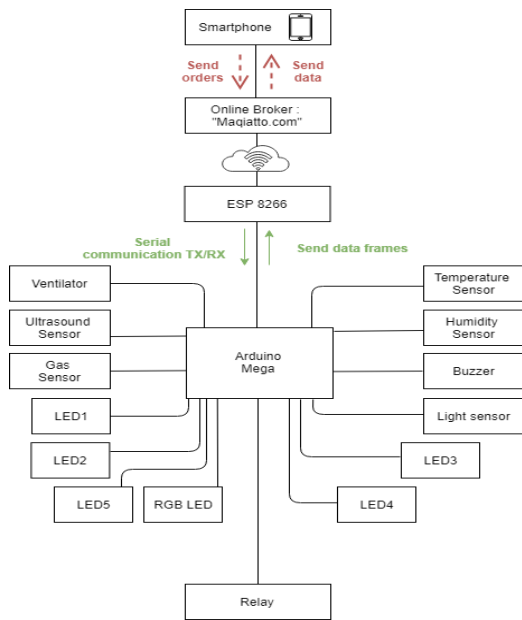


Figure 9. The request path

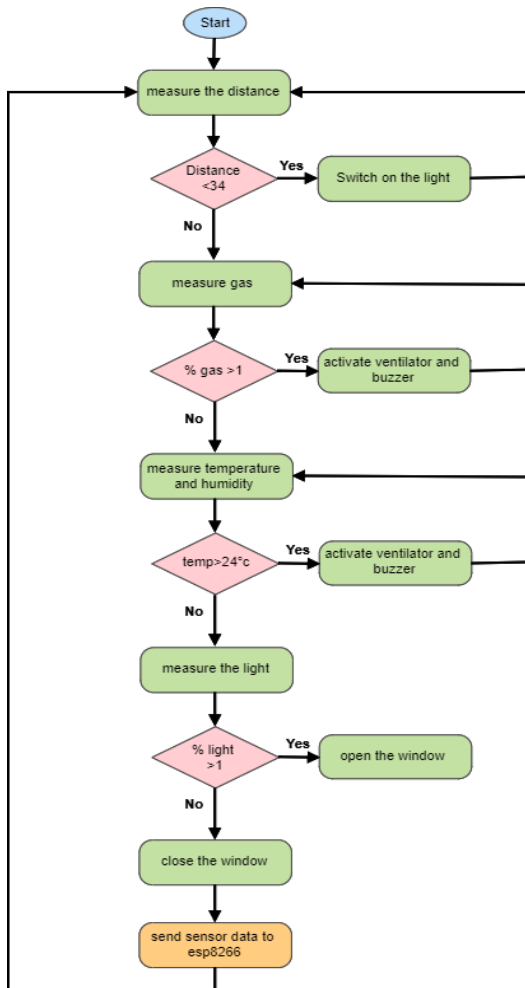


Figure 10. The functioning of the sensors

5 Motivating Scenario and Contributions

This section introduces the scenario that motivated our research. It deals with the design and implementation of a smart house. As we are unable to work on a real house, we have developed a scale model that will allow us to study and simulate the behavior of a real house. Figure 11 describes a simplified version of this house. The house contains 4 rooms, a kitchen, and the couloir.

Each room will contain a lamp that will be controlled remotely. The corridor will contain an ultra-sound sensor with a diode to detect the movement of a passenger: according to the presence of a person, we will turn on and off a lamp. The kitchen has components: Gas sensor, buzzer, lamp, fan.

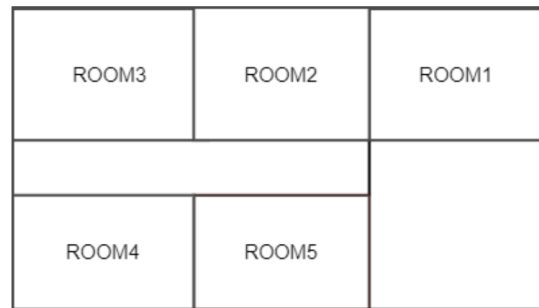


Figure 11. The scale model of smart house

Through this model, we present in table 1 some functionalities of home automation.

Table 1. Functionalities of the home automation

| Location | Devices |
|-----------|---|
| Chamber 1 | -Diode -Light sensor -2 limit switches -Direct current motor |
| Chamber 2 | -Diode -Gas sensor -Ventilator -Buzzer |
| Chamber 3 | -RGB |
| Chamber 4 | -Diode |
| Chamber 5 | -Diode -DHT11 sensor |
| Couloir | -Diode -Ultrasonic sensor |

Our main contributions in this project are:

- Connect to an online Broker (maqiatto.com): which is a server that receives all messages from the clients, then routes the messages to the appropriate destination clients.
- Creation of topics: We have created topics according to our needs (topic temperature/humidity/gas/light) using maqiatto, which is a free, cloud-based, and ready-to-use MQTT, broker for IoT developers and testers.

Topic Management

- Notice your MQTT user name is a prefix for all topics. To get rid of prefixes and be able to use wildcards:

New Topic :

- Available Topics :
 - ben.zouari.safa@gmail.com/gaz
 - ben.zouari.safa@gmail.com/hum
 - ben.zouari.safa@gmail.com/temp
 - ben.zouari.safa@gmail.com/test

Figure 12. Topic creation

- Establishment of the serial communication between the Wifi module and the Arduino board.
- Creation of a mobile application 'Dari MQTT': with which the control of the lamps and the display of the temperature and humidity as well as the gas value. Figure 13 represents the interface connection to the online broker.

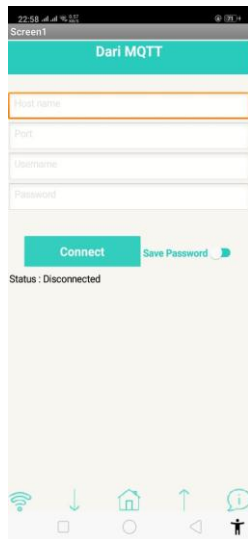


Figure 13. Connection to the online broker interface



Figure 14. The home interface

Figure 14 represents the home interface which includes the subjects to be remotely controlled or to check their values.

Figure 15 presents the light manipulation interface is composed of 4 switchers that ensure the sending of ON/OFF messages. Figure 16 shows the interface for displaying temperature values published by esp8266.



Figure 15. The light manipulation interface

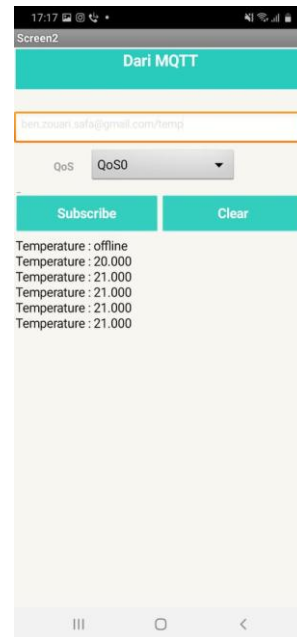


Figure 16. Temperature values published by esp8266

Figures 17 and 18 illustrate the same idea for the humidity and the gas interface (The interface of gas has a different concept of humidity and temperature).

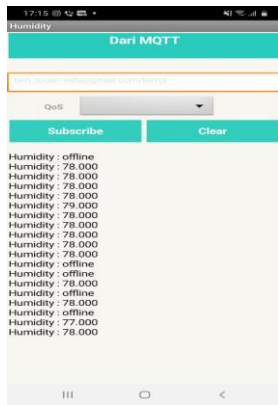


Figure 17. The humidity interface



Figure 18. The detection of gas interface

- Construction of the house: We made the wooden house (prototype) where all the components and sensors will be implemented (figure 19).

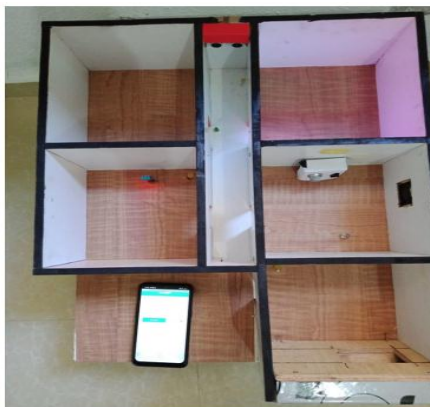


Figure 19. The proposed prototype

6 Conclusion

Automation systems are becoming more and more popular nowadays and are used in many different areas. It aims to provide technical solutions to meet comfort needs (energy management, lighting, and heating optimization), security (alarm), and communication (remote control, visual or sound signals, etc.) that can be found in homes, hotels, public places, etc. In this work, we design an automated house to monitor lights, the temperature, and humidity, and also to warn in case of gas leakage. The design has successfully been implemented through the development of a prototype and tested both hardware and software with the aid of the MQTT Protocol. For our future work, we aim to extend our prototype by including more functionality like home energy management, home safety, home comfort, and other related services with the appropriate sensors.

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