

MQTT based Home Automation System Using Raspberry PI 3 model B

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Abstract : By the virtue of blooming automation industry and wireless connectivity, all the devices within the home can be connected. This improves the comfort, energy efficiency, indoor security, cost savings of the home. Small and constrained embedded devices are used to remotely monitor the conditions within home and control the home appliances. In such case, power consumption and network bandwidth become a major concern. A low power device that transmits messages through a less verbose protocol is needed. Owing to the ubiquitous availability of WiFi, all the appliances within home can be connected through a common gateway. An overview of a light weight Message Queuing Telemetry Transport (MQTT) protocol is presented here. In the prototype, we attempt to implement MQTT on Raspberry PI, a WiFi based development board. Sensors and actuators are connected to Raspberry PI and a Mosquitto based MQTT broker is established for remote monitoring and control. The use of MQTT hence achieves the desired result with a lower overhead and at about a 93% faster speed. The intruder detection is an added useful functionality to the system.

Index Terms- MQTT, Raspberry PI, Mosquitto, Home Automation, Intrusion Detection, Remote Appliance Control, Light-weight Protocol, WiFi, Remote Security Control, Embedded Devices.

1. INTRODUCTION

Home automation refers to remotely monitoring the conditions of home and performing the required actuation. Through home automation, household devices such as TV, light bulb, fan, etc. are assigned a unique address and are connected through a common home gateway. These can be remotely accessed and controlled from any PC, mobile or laptop. This can drastically reduce energy wastage and improve the living conditions besides enhancing the indoor security. Owing to the rapid growth in technology, the devices in the recent past are becoming smart. The real world devices are being equipped with intelligence and computing ability so that they can configure themselves accordingly. Sensors connected to embedded devices along with the low power wireless connectivity is facilitates to remotely monitor and control the devices. This forms an integral component of Internet of Things (IoT) network. can be correctly identified using Graphology. Internet of Things can be considered as a network of devices that are wirelessly connected so that they communicate and organize themselves based on the predefined rules. However these devices are constrained in terms of their resources. Hence light weight protocols such as MQTT, CoAP etc. are used for the data transmission over wireless connectivity. There are so many kinds of radio modules out of which GSM, 3G, WiFi, Bluetooth, Zigbee, etc. are common. However, owing to the surging number of WiFi hotspots and range sufficient to perform the required control and monitoring, WiFi is chosen as the mode of communication in the prototype and the devices are controlled through MQTT protocol implemented using Raspberry PI. MQTT is thus a light weight protocol that occupies low bandwidth and consumes less power. Considering the ease of wireless internet access through WiFi, MQTT client application is built on Raspberry PI. A prototype of MQTT based home automation system is implemented on Raspberry PI. The sensors and actuators connected to Raspberry PI are remotely monitored and controlled through a common home gateway. Thus the existing infrastructure can be used to enhance the home appliances and make them smart. This implementation provides an intelligent, comfortable and energy efficient home automation system. It also assists the old and differently abled persons to control the appliances in their home in a better and easier way.

2. LITERATURE REVIEW

Bluetooth based home automation system using cell phones

In Bluetooth based home automation system, the home appliances are connected to the Arduino BT board at input output ports using relay. The Bluetooth connection is established between Arduino BT board and phone for wireless communication. One circuit is designed and implemented for receiving the feedback from the phone, which indicate the status of the device.

Zigbee based home automation system using cell phones

To monitor and control the home appliances the system is designed and implemented using Zigbee. The device performance is record and store by network coordinators. For this the Wi-Fi network is used, which uses the four switch port standard wireless ADSL modern router. The message for security purpose first process by the virtual home algorithm and when it is declared safe it is re-encrypted and forward to the real network device of the home over Zigbee network, Zigbee controller sent messages to the end. To reduce the expense of the system and the intrusiveness of respective installation of the system Zigbee communication is helpful.

GSM based home automation system using cell phones

The home sensors and devices interact with the home network and communicates through GSM and SIM (subscriber identity module). The system use transducer which convert machine function into electrical signals which goes into microcontroller. The sensors of

system convert the physical qualities like sound, temperature and humidity into some other quantity like voltage. The microcontroller analysis all signal and convert them into command to understand by GSM module.

Home automation using RF module

The important goal of Home Automation System is to build a home automation system using a RF controlled remote. RF remote is combined to the microcontroller on transmitter side that sends ON/OFF signals to the receiver where devices are connected. By operating the stated remote switch on the transmitter, the loads can be turned ON/OFF globally using wireless technology.

MQTT Protocol

The basic concepts of it is publish/ subscribe and client/broker and its basic functionality is connect, publish, and subscribe. Also it has several good features like quality of service, retained messages, persistent session, last will and testament and SYS topics. MQTT decouples the space of publisher and subscriber. So they just have to know hostname/ IP and port of the broker in order to publish/subscribe to messages.

3. ARCHITECTURE AND FLOWCHART OF SYSTEM

In the prototype, we attempt to implement MQTT on Raspberry PI, a Wi-Fi based development board. Sensors and actuators are connected to Raspberry PI and a Mosquitto based MQTT broker is established for remote monitoring and control. The Architecture is shown in Figure 1 followed by the flowchart which is shown in Figure 2.

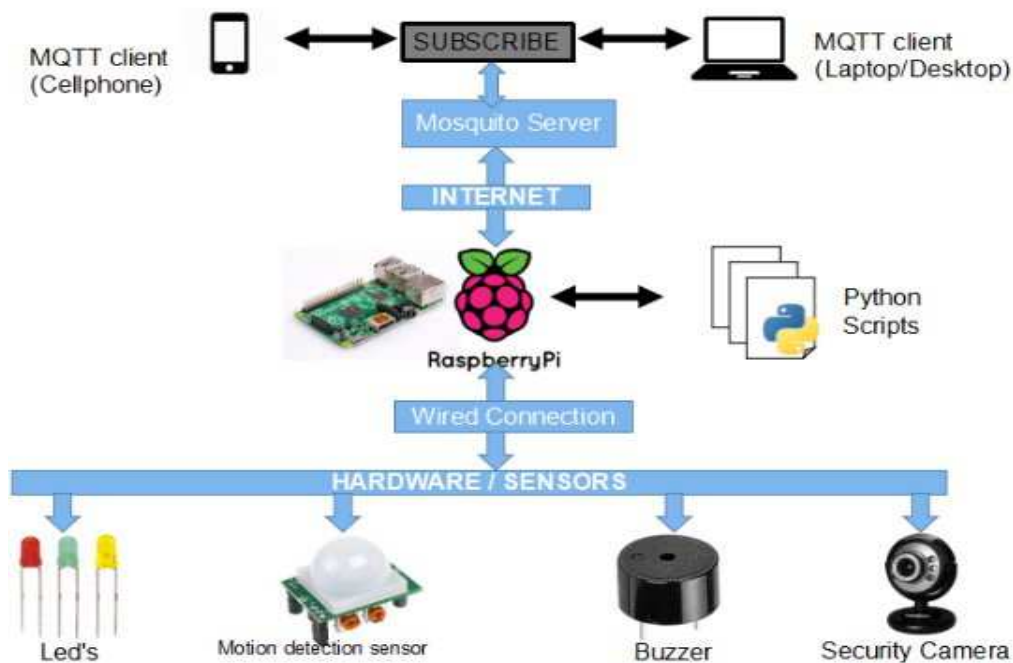


Figure 1: Architecture of MQTT-based Home Automation System

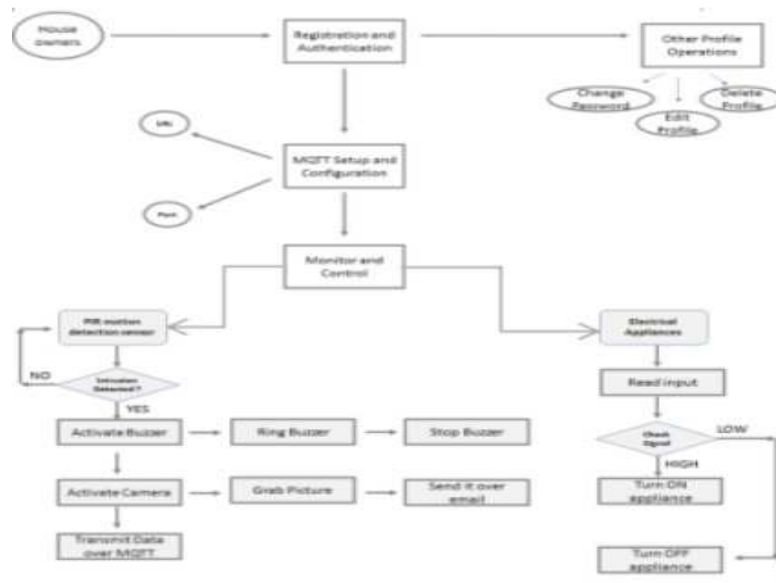


Figure 2: Flowchart of home automation system

The house owner initially performs Registration and Authentication, after which they can perform profile operations such as changing password, editing profile. Then MQTT Setup and Configuration is performed using URL and Port number, after which owner will be able to monitor and control the appliances. PIR motion detection sensor checks if the intruder is detected, if yes, it activates the Buzzer and Camera module. Buzzer rings for certain duration of time and then stops, Camera grabs the picture and sends it through mail to the end user. Electrical appliance module reads the input from user and checks the signal, if HIGH it turns ON the appliance, else turns OFF the appliance.

4. SET OF MODULES

The current work focuses on achieving an automated home control system which can be made a reality by breaking the entire set of operations into six modules as given below.

Module 1: User registration and headless Raspberry PI set up and configuration:

End user first creates account and logs in, after this end user can perform profile operations, then he should perform MQTT setup and configuration using URL and port number to indicate where MQTT server is present.

Algorithm:

Step 1: register the user by providing necessary credentials

Step 2: Setting up the raspberry pi:

-Write the Raspbian OS onto the SD card connected to the raspberry pi.

-Burn the OS into SD card after formatting it

-Configuring the raspberry pi:

-Install WinSCP software which helps in transferring files between the system and raspberry pi over a network using SSH.

-Install putty which helps to execute the programs as the Raspbian OS is built on Linux platform.

Module 2: Implementation of PIR motion detection module:

When unusual motion or movement is detected by PIR motion detection sensor, it transmits this data to the end user via Raspberry pi, which makes use of MQTT protocol for communication. Whenever intruder is detected it will automatically activate the buzzer and camera module.

Algorithm:

Step 1: align the motion sensor such that it is in the range of the camera view.

Step 2: do the necessary connections on the breadboard with the motion sensor.

Step 3: use M2F jumper cables to connect the corresponding breadboard pins to the Raspberry PI.

Module 3: Implement the Buzzer module:

Whenever the intruder is detected PIR motion detection sensor activates this buzzer, which rings for certain duration of time and stops. In this buzzer module we are making use of Piezo buzzer or passive buzzer.

Algorithm:

Step 1: do the necessary connections on the breadboard with the Piezo buzzer, as given below.

Step 2: use M2F jumper cables to connect the corresponding breadboard pins to the Raspberry pi. Connect one pin to ground (either one) and the other pin to a square wave out from a timer or microcontroller. For the loudest tones, stay around 4 KHz, but works quite well from 2KHz to 10KHz. For extra loudness, you can connect both pins to a microcontroller and swap which pin is high or low ('differential drive') for double the volume.

Module 4: Implementation of the Camera section:

Whenever the intruder is detected PIR motion detection sensor activates this camera section, which grabs the picture or image of the intruder and sends it to the user through email.

Algorithm:

Step 1: align the motion sensor such that it is in the range of the camera view.

Step 2: connect the web camera to the raspberry pi board via the USB connecting cable

Module 5: Implementation of the electrical appliances module:

This module enables the owners of the home to control the smart electrical appliances of their home from a remote Location (ideally a different geographical area). The end user will be provided with a couple of MQTT client applications to do this. The first one being the web application which will be developed from the scratch as part of this project research, and the second one will be the mobile application named 'MyMQTT'. There are several other readily available MQTT client applications for both android and IOS, which can be readily incorporated by the owners of the home to control the electrical appliances. As part of this project research is considered, we will enable the owners to perform the turn ON and turn OFF functionalities of the electrical appliances which can further be extended to various other features in the future work.

Module 6: Implement the MQTT module:

Initially configuration of Mosquitto server is done. when end users subscribe to this server, the server reads the input from user and forwards this data to raspberry pi which implements the operation, and when intrusion is detected it forwards the data to Mosquitto server, which will forward it to the cell phone or laptop which is subscribed to server.

Algorithm:

Step 1: execute SQL commands on MySQL to connect and import all packages.

Step 2: through putty, verify connections

Step 3: execute each of the previous modules.

Module 7: Implement the web server module:

This module is an end user interface through which the owner can control and access the home appliances.

Algorithm:

Step 1: Design the web page which accepts user credentials.

Step 2: using bootstrap to improve the look and feel of the web page.

Step 3: get the input from the user

Step 4: check if the input data is valid or not, if yes, go to step 5, else go to step 3

Step 5: enter the user's account and provide various available service options.

5. IMPLEMENTATION

This project is implemented considering the following aspects:

1. Usability Aspect:

The usability aspect of implementation of the project is realized using two principles:

a: The project is implemented as a Java application.

b: The user-friendly interface using Java's view architecture.

2. Technical Aspect:

The technical aspect of implementation of the project is realized as explained below:

STEP 1: INSTALL THE FOLLOWING SOFTWARES:

Servers: Apache Tomcat is to develop the product.

Database: MySQL is used as the database utility here, which is the world's most widely used open source relational database management system (RDBMS) that runs as a server providing multi-user access to a number of databases.

IDE: Eclipse is used as the Development environment on which the JAVA programs would be run.

The following steps should be followed to install eclipse:

-Installation of JVM: Regardless of the operating system, some Java virtual machine (JVM) has to be installed.

-Download Eclipse from the Eclipse Downloads page

STEP 2: WRITE IMAGE TO SD CARD:

Write the image to SD card. an image writing tool is to be used to install the image you have downloaded on your SD card.

Etcher is a graphical SD card writing tool that works on Mac OS, Linux and Windows, and is the easiest option for most users. Etcher also supports writing images directly from the zip file, without any unzipping required.

STEP 3: ADD "SSH" FILE TO THE SD CARD ROOT:

Enable SSH by placing a file named "ssh" (without any extension) onto the boot partition of the SD card

STEP 4: BOOT THE RASPBERRY PI:

The steps needed to be followed for this are:

1. Install mosquitto (MQTT) components.

2. Configure mosquitto and restart the service.

3. Run/ Test mosquitto

. STEP 5: DEVELOP THE WEB INTERFACE AND OTHER REQUIRED FILES AND EXECUTE:

On the Eclipse IDE, use javascript and java to develop required components for the communication and remote control of the appliances. Also use HTML, Bootstrap and related web development tools and languages to develop the user interface. Using these, give the necessary commands and execute the desired operations.

6. RESULTS

The Home Automation System was tested with respect to unit testing, integration testing and system testing with each providing 100% accurate results here is the report of the System testing which was carried out.

Name of the Test	System Testing
Item being tested	Over all functioning of GUI with all functions properly linked.
Sample Input	Sample intruder and the electrical appliances signal
Expected Output	All the modules working as expected
Actual Output	Each appliance reacts as per the signal given and intrusion aptly detected and image of intruder is sent immediately as E-mail.
Remarks	Successful

The implementation of the system is carried out and the execution results are shown in the below images.



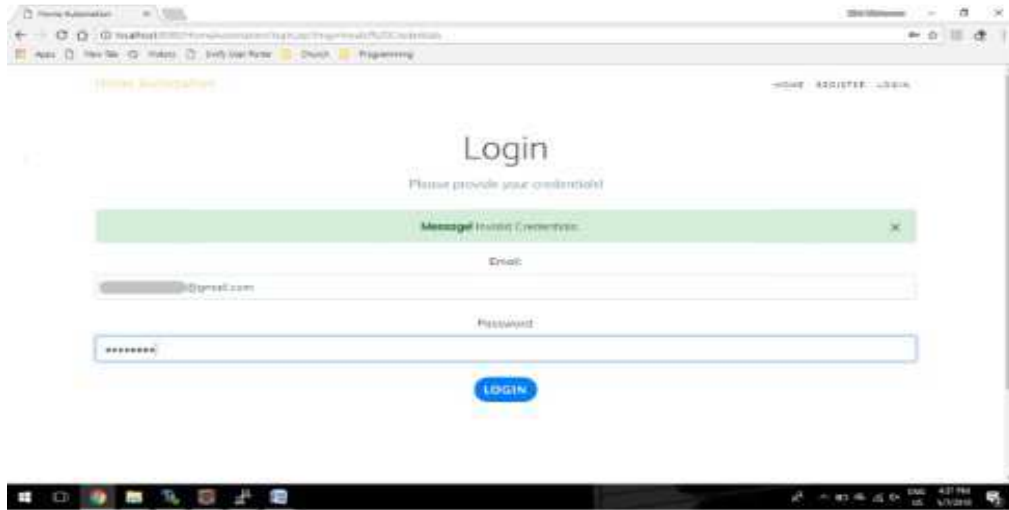


Figure.3. GUI of the MQTT-based Home Automation System

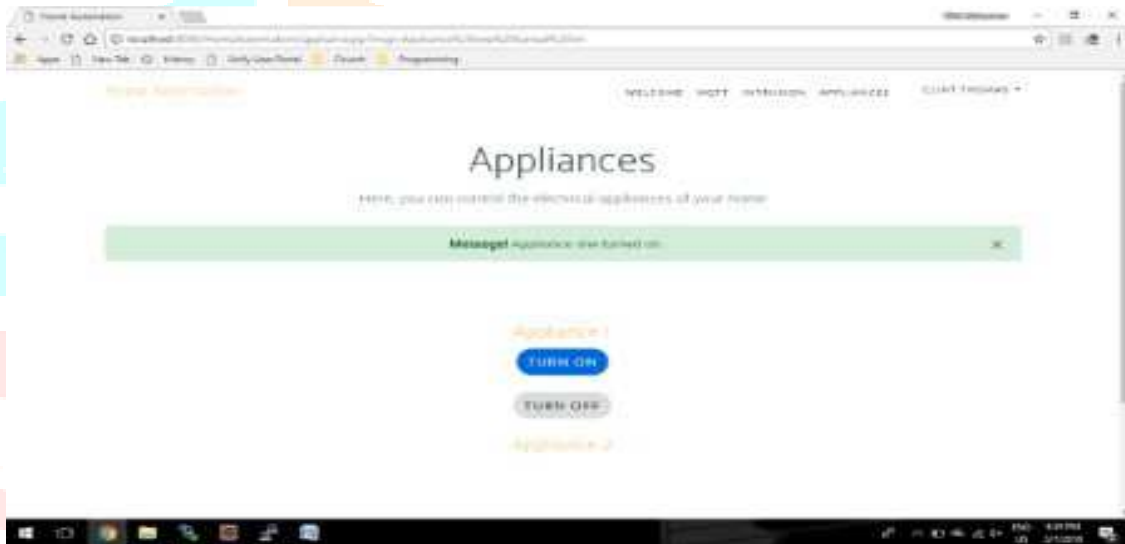


Figure 4: Appliance Control

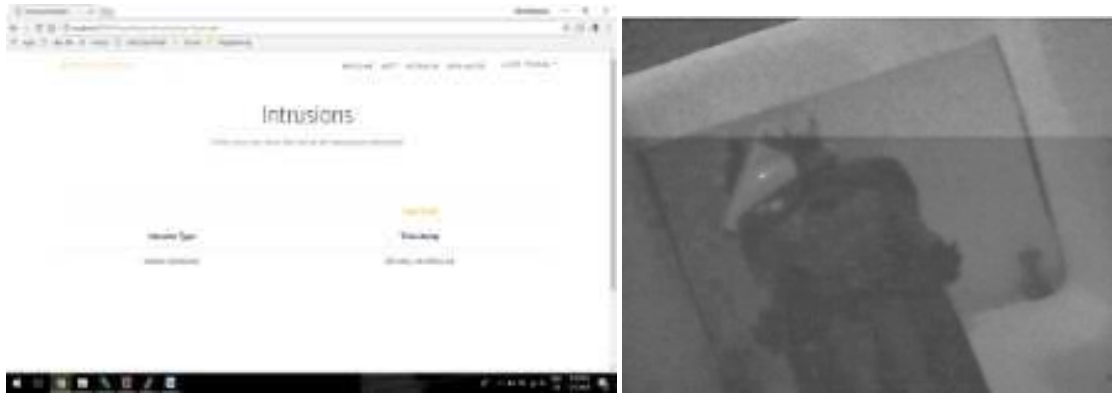


Figure 5: Intrusion detection notification and captured Intruder Image

CONCLUSION AND FUTURE SCOPE

MQTT is thus a light weight protocol that occupies low bandwidth and consumes less power. Considering the ease of wireless internet access through Wi-Fi, MQTT client application is built on Raspberry PI. A prototype of MQTT based home automation system is implemented on Raspberry PI. The sensors and actuators connected to Raspberry PI are remotely monitored and controlled through a common home gateway. Thus the existing infrastructure can be used to enhance the home appliances and make them smart. This implementation provides an intelligent, comfortable and energy efficient home automation system. It also assists the old and differently abled persons to control the appliances in their home in a better and easier way. A further scope in this work can be viewed in taking this further ahead. A cloud platform can be used to aggregate, analyze and visualize data. Customized GUI can be developed to remotely access the devices to monitor and control them. A household security system integrated with a home automation system can be developed which can provide additional services such as remote surveillance of security cameras over the Internet, or central locking of all perimeter doors and windows. Further research can help in development of Occupancy-aware control system, where it is possible to sense the occupancy of the home using smart meter-sand environmental sensors like CO₂ sensors, which can be integrated into the building automation system to trigger automatic responses for energy efficiency and building comfort applications.

Appliance control and integration with the smart grid and smart meter can be made a reality, taking advantage, instance, of high solar panel output in the middle of the dayrun washing machines. Leak detection, smoke and CO detectors can be made more efficient and reliable using this technology. Indoor positioning systems can be improved by home automation for the elderly and disabled. All of the above can be combined and a pet monitoring system can be realized which helps the people monitor activities in their absence.

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