Design of IoT based Platform Development for Smart Home Appliances Control

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Abstract. The advent of industrial automation has brought about a substantial change in the human lifestyle and the way human interaction with machines. One of the major technological interventions in day-to-day life is the role of automation, which has uplifted the living standards in developed countries and fostered humans' dependency for accomplishing recurring tasks. The latest and most adopted technology for remotely monitoring and controlling any machine or device is the Internet of Things - which has become one of the industry standards for automation. Multiple edge computation capable embedded devices and machines are connected to the internet as independent nodes, which can be monitored and controlled remotely with the use of IoT. Adapting this cutting-edge technology for household appliances to monitor and control them is often seen nowadays. This is fast and reliable but arrives with its own snags such as availability of internet at place where user and also the device/appliance is located, use of single control strategy which hampers and restricts the user always to carry the remote or to stay in the vicinity of the device to be controlled in case of wifi or Bluetooth controlled automation. The proposed research focuses on the adoption of multiple strategies to control each device/appliance to empower the end-user without being restricted to a single strategy remote controlling system. The core part of the proposed research revolves around the Message Queuing Telemetry Transport (MQTT) protocol but can be activated with multiple routes such as touch-based sensing panels, cellphone-based controlling, web-enabled controlling or even gesture-based controlling of the appliances resulting in an ameliorative user experience and interactions with machines.

1. Introduction

The Internet of Things is one of the fastest-growing fields in technology, and its applications can change the billions of lives style around the world. They apply it to everyday mobile devices, wearable devices, Google glass, Apple watch, and smart watches. In general, it allows objects to be sensed and regulates remotely in the existing network infrastructure. This system has improved efficiency, accuracy, and benefits while we are far from our home. Different research works related to smart homes are released, but this project pretends to be completely different. In this application, the camera is using for sending the current situation data to the server. Stored data or information will access from anywhere, at any time, by anyone, in this busy and comfortable lifestyle people. Smart automation
means reducing human time, efforts and it provides energy efficiency. Smart Home design uses the Message Queuing Telemetry Transport (MQTT) protocol to be friendly with other remote control devices compatible with various devices to remote control and data collection. Referred paper authors have explained how to control home appliances only through WiFi or Bluetooth or remote separately using sensors. The most important feature of this project is to maintain home appliances using various switches. This paper aims to build a system for operating home appliances automatically, remotely, and manually. The main purpose of this project is to control any type of Window Curtain from anywhere automatically first paragraph after a heading is not indented (Bodytext style).

At home, handicapped, elders, sick people, or kids can also control them through various controllers like Capacitive Touch Sensor, Bluetooth, Keypad, Pushbutton, Remote, or WiFi. It gives flexibility, reliability, and convenience to people. The controlling process can improve the user's good life experience. If the user is unsure whether any home appliances are off or on, they can change the status accordingly from the Domoticz online data log. Domoticz is one of the open-source platform. In this project, Raspberry pi is used as a server. The WiFi is connecting to the mobile over the server. The controller is programmed to send and receive the signals via an Arduino Uno and ESP.

Bluetooth is used to set up wireless communication between the cell phone and the Arduino Uno board. The Android cell phone application is developing to provide a convenient graphical user interface for remote control on any device. Even if Bluetooth and WiFi are not connected, it can control through the Remote controller, and even if the remote is also misplaced, it can handle it through a wall-mounted Touchpanel. It is always fixing to the wall; hence it will not be possible to lose because it is internally connected through wires. If the end-user desires any changes, it will provide much more freedom and easier access. Here, the camera is also using to detect the current status of the devices. Here the camera is using to send the current status data to the server. This design platform has been developing to automatically build a system for all home appliances operations remotely and manually. It can control and monitors various devices such as Light, Fan, TV, AC, Window Curtains from anywhere such as home, building, or office. At home, handicapped, elders, sick people, or kids can also control them through various controllers like Capacitive Touch Sensor, Bluetooth, Keypad, Pushbutton, Remote, or WiFi.

2. Literature Survey
The solution framework consists of three distinct features: design platform, a protocol used, and the application-specific scenario. In this section, a review of the current work is presenting.

In [1], the author proposed a review of Smart Home Systems and office systems with software and hardware. In this paper, home proxy and remote server using XMPP protocol for remote control are discussing. The author has used a home proxy to solve the simultaneity problem. The proposed system supports the multiple user facility. They are exploring how they can manage or control more than one Smart Home System by registering different home proxies. In [2], the author studied object labeling, object recognition, and wireless transmission. Here, Bluetooth has used to transfer the information to the user in any dangerous event (Ex. in case of fire). In a hazardous event, it alarms immediately using the video surveillance system technique. This type of implementation will help take care of children and adults. It gives alarm information quickly about that situation. In [3], the authors proposed TCP/IP and BLE (Bluetooth Low Energy) selected as a wireless communication protocol. This architecture is to provide them all systems with a high degree of flexibility. It adjusts to several environments and is also compatible with the Smartphone. This paper discusses different network layers for communication. This architecture is heterogeneous and flexible. In [4], the author explores developing device management platform IoT, HTTP protocol, MQTT, and XMPP protocols. This architecture has been designed using a cloud-based platform. In this architecture system, the AllJoyn platform is used, which is the most common data exchange system, between an intelligent gateway and remote applications. The system simultaneously interacts with various IoT gateways and IoT devices. In [5], the authors solve the possible service dispute in a multiple control center. The essential point to solve this problem is to add a unique service identifier (USID). It is the device identifier of the control center.
as a parameter of the events and action method. In [6], the author has explained the data acquisition and control system. Bluetooth Low Energy (BLE) has been used in this system because of its low cost and short-medium communication range. This paper aims to create a system that uses BLE to obtain the specification, which supplies the messages to control the home controller.

Having considered the design platform's existing features, it is also reasonable to look into the IoT protocols developed for the system.

In [7], the authors have studied the efficiency and applicability of various machine-to-machine protocols. Many protocols can be used in IoT, such as HTTP, XMPP, CoAP, MQTT, BLE, etc. MQTT and HTTP protocols have been selected after they have been studied; these two protocols have their advantages in diverse cases. CoAP is a robust power management protocol, and it is suitable for utility field area networks. MQTT is using for IoT messaging and nodes without power constraints, and both are lightweight protocols. In [8], the authors have proposed how to make easy intercloud interoperability and light. They have examined that REST with XMPP is the best convention for intercloud communication. Since it permits special activities and can be used to empower access, make, erase, or adjust assets of an XMPP element. The protocol will apply the REST architecture style to XMPP entities, eliminating the limitations of HTTP.

Consequently, administrations are discoverable and explorable various information and yield sorts of definitions are conceivable. According to these applications, REST with XMPP protocol is implemented in the RWX4J framework. In [9], the author's purpose of this paper is to control multiple appliances from anywhere in the world at a low cost. This method included Raspberry Pi and a web server. In this method, MQTT and HTTP protocols have been using. Here HTTP protocol is used to transfer location-based information, and MQTT is used to publish/subscribe message services in smart home systems. This system contains many clients and one broker. In this project, Smart-Phones, PCs, or Laptops are using as a client. Each client communicates with a broker only. In [10], the author presents HTTP behavior, MQTT protocols and prefers the MQTT for good performance. MQTT reduces the protocol overload and provides high-efficiency communication for IoT. In this proposed system, protocol overloading and tiny data-blocks are serious problems. The opinion of this paper is MQTT function is better than the HTTP protocol. In [11], the authors have proposed changes in the ongoing convention for modern remote work systems with ease and low vitality usage. One of the best examples of this type of application is real-time Bluetooth Low Energy. RT-BLE is also one type of protocol. This Real Time BLE protocol exploits TDMA (time division multiple access), and it delivers data packets with real-time support. Here it proved that RT-BLE is suitable for industrial applications.

It is essential to look at the application scenario development in the IoT automation model. The design applications considered here are the curtain control unit, which is used at home, theatre, and offices.

In [12], the author has designed for office workers, disabled persons, and elders in household activities. When they are on a trip or outside the home, and if they have forgotten to close the windows, windows can be closed automatically with WiFi. The device automatically detects environmental factors, such as light, rain, humidity. These ecological factors are then converting into brightness, moisture, temperature, etc. With the help of these factors, windows will be automatically open or closed. In [13], the authors have explored the implementation of control and monitoring systems for smart homes with the help of sub-controlling systems. It consists of many subsystems, such as a wireless Bluetooth technique and remote control technique. The WiFi controller can control anywhere in the world. This type of system shows that safe, great flexibility, and reliability. In [14], the authors have presented how to control automatic room temperature. In this project, the controller compares the outside and inside the room temperature. This difference affects the compressor speed, and this speed sets the desired point. It involves a mathematical model of an air-conditioning system. It analyzes the performance of the designed controller using the help of Matlab software.
3. Proposed Work

The observation in the existing design look on IoT automation promotes a keen interest or unique control unit for all types of home appliances such as light, fan, TV, Refrigerator, or curtain-automated movement. Further, the communication protocol to send input signals needs closer attention.

3.1. Product (Prototype) Design

The designer can choose the correct and appropriate processor or controller, sensors, actuators, and communication protocols for the system's desired type. A communication protocol is one of the essential considerations. The right protocol supports fast, lightweight, and one of the best examples is MQTT. The interface is the crucial correspondence protocol and equipment mix used to send and get messages between various devices. The architect chooses the client's detection necessity and settles on the obliged sensor to play out the related task, a sensor or actuator assignment. Sensors transform energy into electrical data that mean it converts the analog to digital. The Capacitive Touch sensor acts as a button. Actuators transform electrical data into energy (eye, ear, and muscle of IoT). In this project, actuators are used to slide Home Window Curtains or Office Window Curtains. Fig 1 shows the block diagram of Home Appliances Control through different controllers.

![Figure 1. Block diagram of Home Appliances Control through various controllers.](image)

3.2. Control Communication Mechanism

This project is to build a system nicely that means the operations of all home appliances such as light, fan, AC, TV, and Window Curtains automatically, remotely, and manually. It controls and monitors various devices from anywhere through multiple controls; all mechanisms are explained here.

3.2.1. WiFi Control Design Mechanism.

WiFi(Wireless Fidelity) is a technology; it uses radio waves to give availability. It provides availability to different devices by discharging frequencies between 2.45 GHz to 5 GHz. It can go anywhere or anyplace, for example, at the office, home, school, hotels, or colleges. It is a remote system. It acts as a broker, the information gets from the web, and it will go through the switch to be coded into a radio signal[16]. These radio signals will provide by the (Personal Computer) PC or a connector. Here a decoder means a router, and WiFi is a high-speed Internet connection. In WiFi, the most critical and essential elements are the router, antenna, and radio signals. WiFi allows the user to get access to the web at any-place. This project has been reproducing smart lights connected wirelessly through WiFi to approve users to access remotely related dashboard snapshots (Graphical User...
Interface) shown in the below Figure 2. In this product, ESP8266 12e is using as a WiFi module Wireless Transceiver. The access point and base station consist of ESP8266 12e. It communicates with the internet and transfer data to the hosting server (Raspberry Pi) or a Smartphone.

![Image of Domoticz Dashboard snapshot(GUI)](image)

**Figure 2.** Domoticz Dashboard snapshot(GUI).

3.2.2. *Bluetooth Control Design Mechanism.*
Bluetooth is wireless technology. It works as a master or slave configuration. The range of this module is about 30 feet. It operates in two modes, one is command mode, and another is data mode. This module connects to the last device automatically. It works fine for many applications. Bluetooth module first checks the Bluetooth position of the Smartphone (Bluetooth is OFF or ON). After searching for data, this module sends this data to the Arduino. These data compare with the Arduino code, and it starts pairing between Bluetooth and mobile phones. If a pairing occurs, the respective relay gets ON and OFF. Hence, the motor driver drives the signal to the motor according to the relay input. The HC-05 device exchanges the data over short distances from the settled and mobile devices, and it is a serial port protocol module. This Android phone application is written in the PHP language. The Bluetooth module acts as an interface between the mobile and the Arduino board shown in Figure 3.
3.2.3. IR Remote Mechanism.
IR (Infra-Red) remote used infrared light. Nowadays, it can manage several devices at a time. In this controller mechanism, the remote emits the light, and the phototransistor receives it. Hence, it receives and transmits signals to other devices through radio waves. Below, Figure 4 shows the mechanism of remote control curtains using an IR remote. This device consists of two sections, such as a transmitter and a receiver. The transmitter section works as a standard remote, and the receiver section remains constant. That means this receiver section is connected to any load, like light, TV, Fan, etc. Remote operates from a distance of 30 feet. Thus it can control 3 to 6 lights, fan, socket, window curtains at a time. The main advantage of this remote through control is, it saves redundant wiring, and it is a perfect option for patients and older people. It can activate about 10 meters distance.

![Figure 3. HC05 Bluetooth Curtain Control Design Mechanism.](image)

![Figure 4. Remote through curtain control.](image)
3.2.4. **Touch Panel Mechanism.**
A stable detection technique can cover various quality conditions. It does not require any activation force and connects through the non-conductive dielectric material. The application is utilized rather than old mechanical switches or catch, making it conceivable to deliver interfaces with a glass or polycarbonate surface up to 8 mm in width. The electric field is created from this capacitive board when responding to the client's touch and squeezed. Touchpanels are three types: they are four-channel touchpad, eight-channel touchpad, and 16-channel touchpad. Capacitive Touch Sensor is used to control the one horizontal curtain movement design.

3.3. **Server Design**
The software is implemented using the Embedded C++ in the Arduino IDE and Python in the Raspberry Pi. Two main programs are running in the system: Arduino IDE and another one on Raspberry Pi. The main part of any IoT-based operation is a server design, and this design is shown in Figure 5. In this project, Raspberry Pi works as a server. The server acts as a distributor and provides services for different homes, rooms, and offices. The WiFi module is connected to the web and by the Domoticz dashboard enlargement for user monitoring and control. Here it operates using MQTT (Message Queuing Telemetry Transport) protocol. The principal goal of this sort of plan design development for IoT applications is a modest and open-source home robotization framework. This robotization framework is fit for controlling. It also merchandised most of the house, theater, industry, and office appliances through a simple tractable web interface to run and keep up the framework. The proposed secure remote LAN connection between dispersed equipment modules and the server is secure communication between clients and the server. The proposed design system is an appropriated Home Automation framework that comprises a server, equipment, and interface modules. Raspberry Pi is the server controller equipment.

WiFi has enhanced the framework security to build framework versatility and adaptability. The primary capacity of Raspberry Pi is to oversee, control, and screen-circulated framework parts. It empowers the equipment interface modules to perform their tasks through actuators and set off the occasions from sensors or any info controllers using the Domoticz dashboard shown in Figure 5.

![Figure 5. Server Design.](image)
3.3.1. Protocol
MQTT remains for Message Queuing Telemetry Transport protocol, and it acts as a distributor/endorser; The MQTT protocol communicates in both directions. MQTT is a great degree straightforward and lightweight informing protocol. It has low-data transfer capacity, little battery control, high-inertness, or inconsistent systems. Microcontrollers such as Arduino Uno and Raspberry Pi empower cheap equipment devices, and it quantifies sensor information and sends it through the website. It is for versatile applications where data transmission and develops the overall intelligent development of home automation. The architecture of the MQTT protocol is shown in Figure 6.

The standard port for MQTT to use TCP/IP port 1883 is held for use with MQTT. The MQTT customer has an all-time open TCP connection with the dealer. MQTT dispatches messages to customers, and it gets a message from distributors; again, it dispatches messages from the distributor to supporters. It makes the protocol highly scalable without a direct dependency from the publisher and the subscriber. IoT cloud platforms support MQTT protocol, it sends and receives data from devices or objects, but it does not block the client while waiting for the messages.

The Home Automation sketch is tasked with establishing and maintaining the WiFi module connects to the Raspberry pi. Raspberry Pi is a small computer. Domoticz App Development Software is installed in a Raspberry pi because it is open-source software. ESP8266 12e WiFi library is used to provide the WiFi-module board support for Arduino. MQTT library is used to handle communication between esp8266 12e and Domoticz dashboard located on IO servers and the WiFi-module.

3.4. Curtain Control Flow Chart
The curtain control system controls all-electric curtains such as horizontal, Vertical, Roller blinds, Horizontal blinds, and a Cloth type of curtains. It can be automatically open and close at a particular time or operate the user desired position. Home Automation is a progressive step in the Internet of Things in which everything has been configured with Internet Protocol addresses. It can be monitor, regulate, or access remotely with the help of web technology.

Types of Curtain Products:
1. One Side Sliding Curtain Movement
2. Two Side Sliding Curtain Movement
3. Roller Blind
4. Vertical Blind Angle Movement
5. Theatre Curtain Movement

Figure 6. Server Design.
In some papers, curtain movement is in only one way that it is remote through controlling or WiFi through controlling is published. In this project, curtains can control any switch like a push button, remote, WiFi, Bluetooth, or Touchpanel. Actuators are the main part of the Window curtains. Here DC motors, Stepper motor, and Servo motors are the primary actuators. Selecting the types of motors is depending on the weight of the curtain. This type of design can control window curtains using any kind of input controller. The flowchart is shown in Figure 7.

![Flowchart](image-url)

**Figure 7.** Curtain movement product flowchart.
3.4.1. Motor Design
To develop curtains product requires motors, pulleys, and motor drivers. First, have to understand exact applications and then acquire skills on different characteristics and specifications to ensure the right products. First, it needs to select the motor's specifications, such as size, weight, torque, speed, current, and motor voltages. This model is designed after checking the requirements. In this type of project, DC motors, stepper motors, and servo motors are using according to the specifications and model design. This model is based on the weight of the load, height, costs, and other factors. The speed of closing and opening of a curtain depends on presenting the input controller. Motorized curtains can be used for remote switch operation or manual operation.

A motor shaft can rotate slowly or quickly. RPM (Revolution Per Minute) is the unit of motor rotation. When the speed of the motor is constant, then the work and horsepower are proportional. Equation (1) and Equation (2) shows how to find the torque and power of the motor. If the torque of the motor increases, the horsepower also increases to maintain a constant speed.

\[
\text{Torque} = F \times r \quad \text{Where } F = \text{Force and } r = \text{Radius} \quad (1)
\]

\[
\text{Power} = \frac{\text{RPM} \times \text{Torque}}{5252} \quad (2)
\]

\[
T = F \times r = F \times D/2
\]

- \( T \) = distance between the center of rotation
- \( F \) = force point

**Figure 8.** Torque calculation.

The torque is dependent on the weight of the conveyor, which is shown in figure 8. The magnitude of the rotation is torque. If torque remains constant, then the speed and horsepower are proportional. As the speed or revolutions per minute (RPM) increases, horsepower also increases. Because it maintains constant work, for this reason, speed decreases, and the horsepower also decreases. The positive and negative torques are depended on the direction of the motor rotation. Positive torque shows the counter clockwise direction, and negative torque shows the clockwise direction.
3.4.2. *One Side Sliding Curtain Movement*

One side curtain movement mechanism is shown in Figure 9. It increases power efficiency and comfort in daily life to improve the quality of living. The Arduino powered system opens and closes the curtain on a schedule, based on room temperature or outdoor light using manually, remotely, or WiFi. This mechanism consists of a DC-g geared motor it drives the forward-reverse direction. When activated by the WiFi, the motor, Remote, Bluetooth, Touchpanel, or push button, will turn in either direction depending on the direction of current moving through its principle winding.

![Figure 9. One side sliding curtain movement.](image)

To develop curtains product requires motors, pulleys, and motor drivers. First, have to understand exact applications

3.4.3. *Two Side Sliding Curtain Movement*

In this type of mechanism, a DC motor and four pulleys are used. It is round and a cord pattern arrangement, and attached to the curtain rings. It allows the curtain to be pulled in the opposite direction. In this product, the string or thread is looped over the pulley. It starts from the curtain pole left and another pulley at the right end of the curtain pole. It is rail back over another pulley at the left end. The other pulley is attached to the motor. Here this type of cord moves right, bottom, and left. Hence, it repeats this process. The thread or string moves according to the motor shaft movement. Users can control any type of input switch. The default position of the button is in the middle, and this position is the off position. Users will use Touchpanel, remote controller, push-button, or Bluetooth to open and close the curtain. Two side sliding mechanism with the existing curtain shown in the above Figure 10. It can control any type of input controller or switch. If the motor is in a clockwise direction, it offers to open the curtain, and if the motor is in an anti-clockwise rotation, it shows to close the curtain.
3.4.4. Roller Blind Curtain Movement

Automatic roller curtain allows the user to control the curtain from far by using an IR Remote controller, Bluetooth, or webpage. Press the open button once the relay provides power to the open button side. The roller tube slowly turns until the fabric is completely wound up, which means the stepper motor spins clockwise direction, slowly rolling down the roller. If pressing the close button, the relay provides power to the close button side; hence the stepper motor spins counterclockwise direction, constantly rolling up the roller. Figure 11 shows the roller curtain deployment for existing curtain mechanism.

Figure 10. Two side sliding mechanism with an existing curtain.

Figure 11. Roller Curtain Movement.
3.4.5. Vertical Blind Curtain Movement
Blinds are made up of wood, or they can be leather, aluminum, composite materials, or vinyl. Blinds have various lengths and widths, and they can be horizontal or vertical. It can be adjusted entirely open or closed. Almost all of the Blinds are available in fabric or vinyl content materials. Blinds are made of continuous pieces of fabric that roll up via the pulley mechanism. Vertical blinds work well in light and dark; also, they are effective at blocking light and creating privacy. In this mechanism, The DC motor is used to control the horizontal movement left and right. The servo motor is used to manage the Blind rotation. Arduino takes input from either the input controllers, which correspondingly controls the DC motor through the motor driver.

3.4.6. Theatre Curtain Movement
The DC motor is fixed at the center to one top rod with a wheel next to the rod. Five or six fixed wheels to another rod after connecting the rod1 to rod2 via thread using this wheel at the first rod and center wheel of the second rod. The second rod contains the ropes to all the wheels in it. When the motor of the second rod rotates in a clockwise direction, the curtain moves upwards. Use the mechanism of rings is present at the surface of the curtain. When the thread's motor rotates in a counterclockwise direction, the curtain moves downward using the rings.

4. Field Observations for developed Prototype – Result & Discussion
The proposed work are designed, implemented, and tested for functional correctness. The interface modules send correct control signals to activate the required home appliances, as shown in figure 12; the related data are saved in the backend or the log file. The mobile application developed facilitates the continued sequencing of the design. The design feature to choose appropriate torque using the mathematical model is distinct. The mechanical parts used in the design are durable and of good quality. The weight of the curtain is vital in the design of the electro-mechanical unit.

The emerging idea of the Internet of Things (IoT) and wireless sensor networks is quickly finding their path throughout our modern life. Gradually, by the use of smart devices, IoT would automate everything around us. The use of this technology is a safe and comfortable living environment for everyone. It also proved to contribute to increased independence and safety for many end-user families and carers. The wireless network with Raspberry Pi, Arduino Uno, ESP8266 12e, and several open-source software packages have various attractive features, including compact, low-cost, scalable, easy to customize, and easy to maintain. One of the main advantages of this design lies in integrating Touchpanel, remote, Bluetooth, and WiFi into a single compact. This product is achieved by controlling window curtains through any input mentioned above controllers anywhere, anytime, or any way. This system's benefits include improved conditions to maintain any home appliances if either input controller is missing. Tested the designed product for IoT-based Smart Home Automation on the experimental setup, which is successfully worked
Figure 12. Hardware Configuration setup using various controls of Smart home appliances.

5. Conclusion
This paper proposes that using WiFi, Touchpanel, Bluetooth, and IR Remote control units provides an attractive way for the system design to improve the design unit's ease of usability. Alternatively, providing the electro-mechanical platform for all types of curtain movement is a unique approach. Such a blend of unique hardware design models and integrated system software brings together the proposed product application best. The server model interaction for the IoT design for automation is unique. Sufficient care is taken for customer compatibility in terms of using the design unit. At all points of time, user satisfaction is high.

The merit of the design platform is visible in the IoT-based design platform because if the user phone with an app installed is missing, any other Smartphones can be used due to the availability of target device information in a web server (browser). Using user name and password, and it can secure LAN connection between related hardware module and server. MQTT protocol can be activated with multiple routes such as touch-based sensing panels, cellphone-based controlling, web-enabled controlling, or even gesture-based controlling of the appliances resulting in an ameliorative user experience and interactions with machines. This is demonstrated for curtain products, and it can be extended for other Smart Home Automation systems like Illumination Control, Water level control, Temperature and Humidity control, or Automatic climate control for domestic purposes in the future.

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