Final Report
on
Scene Implementation
in a
Smart Home

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1 Introduction

The invent of the Internet of Things (IoT) has revolutionized the was digital equipment works and communicate in office, home, factories, vehicles, *etc.* A smart home is one such domain in which a large spectrum of IoT devices, such as home appliances, sensors, health and sports activity monitoring equipment, smart watches and communication devices, *etc.*, are involved and facilitate a more secure, energy efficient, smart, and convenient experience to users.

In this work we assess we assess and attempt to simulate scenes from a smart home in which a pre-configured activities are automatically performed by the smart home ecosystems. Further, the user can override the pre-configuration if he/she requires.

1.1 Problem Statement

The problem statement for this project as following

1. Scene implementation in a smart home with user configured, commanded and IoT sensor input triggered actions

1.2 IoT equipment Considered for Simulation

Following IoT equipment have been considered for demonstration of scene in a smart home

1. Motion detectors
2. Smart lights, Solar Panel
3. Ceiling fans
4. Air conditioner
5. Camera
6. Doors
7. Windows
8. CO level detector
9. Fire detector
10. CO_2 level detector
11. Kitchen appliance

1.3 Emulation Platform

Following platform has been used in this project:

- CISCO Packet Tracker v8.0
- MCU for controller implementation
- Python3 as programming language
- Communication: MQTT/HTTPS
- UI: Standard CPT GUI
- Windows 11 on i3 laptop with 6GB DDR

1.4 GitHub Repository

The work, *i.e.* the CISCO Packet Tracer emulation project file, presentation and this report is available at following public repository in GitHub.
https://github.com/Deepakrewa/ELL893CyberPhisicalSystem

2 Pre-configured Scenes

2.1 Good Morning Scene at 0600 hrs

2.1.1 Scene Specification

User has configured his/her smart home to perform a defined set of tasks every morning at 0600 hrs such as watering the garden, opening windows, initiating the kitchen appliances, switching off AC and lights, switching on fan, *etc.*

2.1.2 Decision Making Logic

It is assumed that at 0600 hrs, sun rises and user of smart home has configured the ecosystem initiate the daily routine work. As the sun rises at 0600 hrs, the solar panel starts generating electricity which can be used to save energy in Batteries for later consumption. Further, the gateway device of smart home senses the voltage at output of solar panel and triggers other smart IoT devices as per pre-defined user configuration.

2.1.3 Implementation and Result

In this scene, after receiving a positive feed from solar panel, the gateway device also the edge equipment, initiates following sequences of tasks through multiple IoT equipment:

- The water sprinkler at lawn start watering the lawn.
- The light in the bedroom of user is switched to DIM mode.

- The doors of bedroom, kitchen, and lawn are unlocked.
- The air conditioning is the bed room is switched off.
- The ceiling in the living room is switched on.
- The windows of living room and kitchen are opened.
- The coffee maker in the kitchen is switched on.

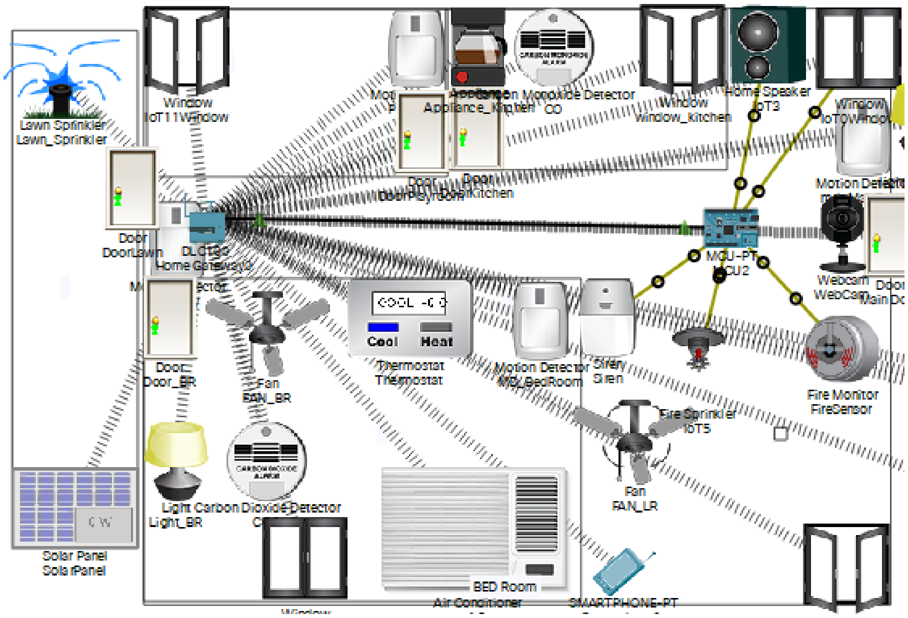

Figure 1: Scene: Good Morning at 0600 hrs

Figure 1 reflects the scene with a pre-configured state is achieved by the IoT equipment deployed in a smart home.

2.2 Main door opens or some one walks by

2.2.1 Scene Specification

This scene relates to physical security and covers two important uses cases when the front door camera should start recording the video of individuals coming in or going out through the main door or if anyone passes near by by the main door. A live stream shall be sent to the smart phone or tablet to alert the owner of the smart home. Hence following two activities shall be registered to enhance the physical security of the smart home.

- Some one physically opens the main door of the smart home.
- Some movement is observed at the main gate of smart home.

2.2.2 Decision Making Logic

If front door of smart home is open then anyone can walk inside. To ensure that the owner is alerted and a video log visitor is maintained, a camera must be deployed which can send life feed to some device of the owner. Further, we need a motion detector to detect and tract movements near the main door of smart home.

2.2.3 Implementation and Result

In this work, the front door of home is equipped with a camera, motion detector, and light. The action is triggered by opening the front door or if someone moves near it (even if the door is closed). The trigger initiates a sequence of actions as indicated below

- light at front door gets switched on
- the front door camera is switched on and started recording
- a live video feed from camera is sent to the smart phone or tablet of the owner

Figure 2 reflects the scene when camera deployed at the main door is off, the door is locked and motions sensor does not detect any activity.

Figure 3 shows a scenario in which the front door camera is on and sending video stream to the smart phone or tablet of smart home owner. It may be noted that camera is capturing movement and door is indicated as open. To trigger this actions sequence, the door was manually opened.

Figure 4 depicts the scenario in which the motion sensor deployed at the front door captures some activity and smart home switches on the camera. The Live feed of camera is sent to the user. It may be noted that in this case the door is still closed.

In both the above cases, i.e. II and III, the smart light deployed at the front door is switched on for better visibility. The system may be made more effective by controlling the light as per the time or visibility. The Light may be switched on only when visibility is poor.

2.3 Fire incident is detected in living room

2.3.1 Scene Specification

Fire breaks out in the living room in the smart home. The home users may be present in the living room or be in any position in the smart home including sleeping.

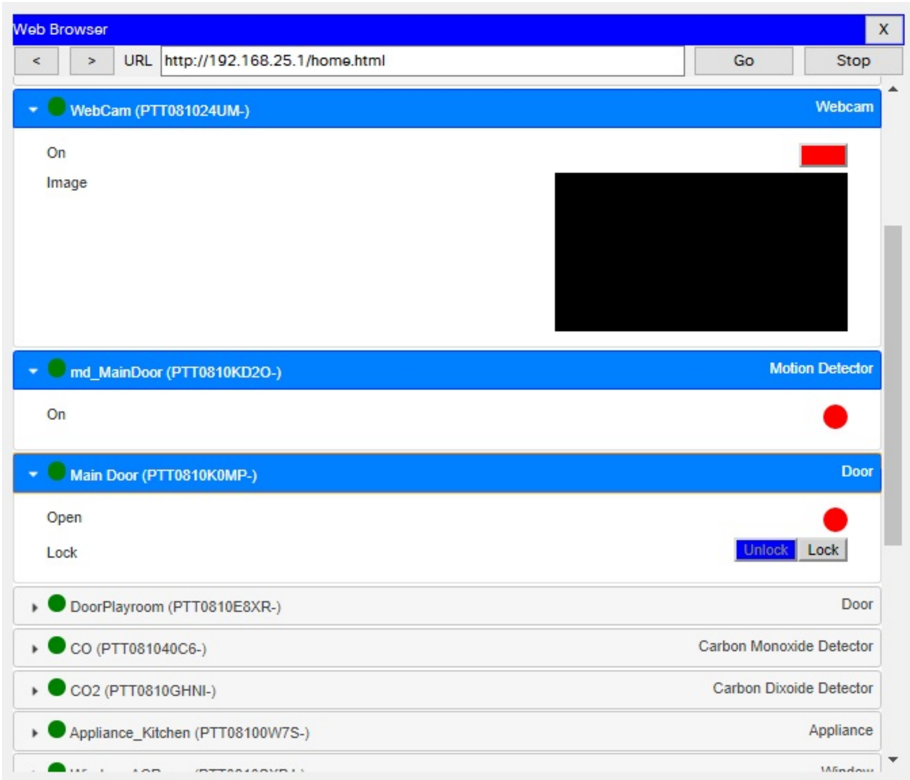

Figure 2: Case-I:Front Door Camera, Motion Sensor and Door

2.3.2 Decision Making Logic

Once the fire breaks out in the home, appropriate measures to contain and eliminate fire needs be activated. Further, users needs to be alarmed and instructed to take necessary action to ensure their safety.

2.3.3 Implementation and Result

The smart home is equipped with a fire detector. As soon as it detects fire incident, the smart home initiates following actions sequence:

- Sound the siren to alert home users
- Initiate fire sprinkler to contain and eliminate fire
- Open all doors and windows to allow fresh air in home and enhance escape routes for home users
- Announce appropriate recorded message through speaker suggesting users to exit the premise to safety.

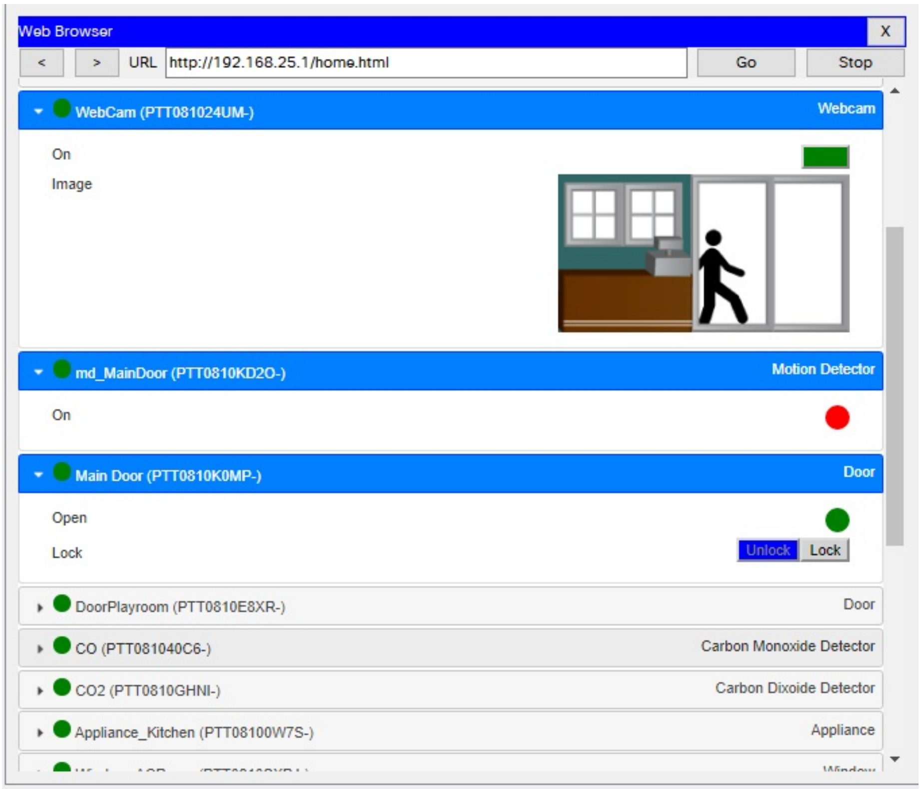

Figure 3: Case-II:Front Door Camera, Motion Sensor and Door

Figure 5 shows a normal condition of smart home, *i.e.* no fire incident is observed. Please note the siren, fire sprinkler and speaker are off and window in closed.

Figure 6 shows a scenario of smart home in which fire incident is observed. Please note the siren, fire sprinkler and speaker are ON and window in open.

2.4 Smoke is detected in Store or Garage

2.4.1 Scene Specification

Smoke is detected in store room or garage and necessary action sequence is required to mitigate it.

2.4.2 Decision Making Logic

In case some smoke is detected in the store room, the IoT controller initiates following action sequence:

- Sound the siren so that owner can know

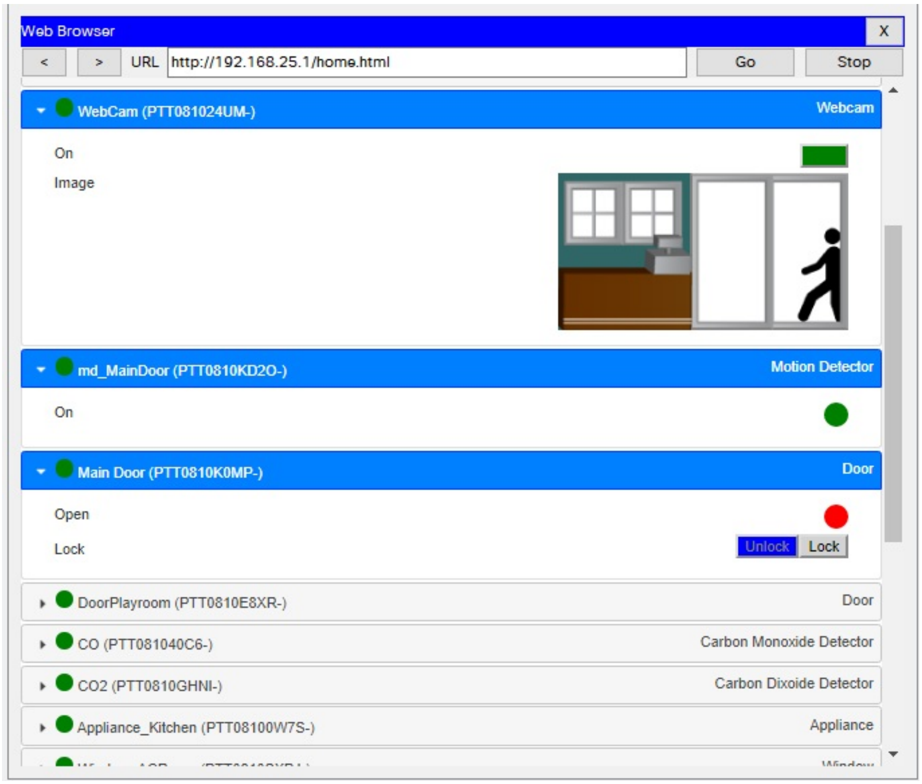

Figure 4: Case-III:Front Door Camera, Motion Sensor and Door

- Start fire sprinkler
- Open all doors and Windows
- If no smoke then switch off sprinkler, however siren and doors and windows needs to be closed with manual intervention

2.4.3 Implementation and Result

The scene is implemented by deploying a smoke detector and fire sprinkler in the store room. It also uses the siren installed in the living room of smart home.

Figure 7 shows a normal condition of smart home, *i.e.* no smoke incident is observed in store or garage. Please note the siren and fire sprinkler are off and garage door in closed.

Figure 6 shows a scenario of smart home in which smoke is detected in store room or garage. Please note the siren and fire sprinkler are activated and garage door has been opened.

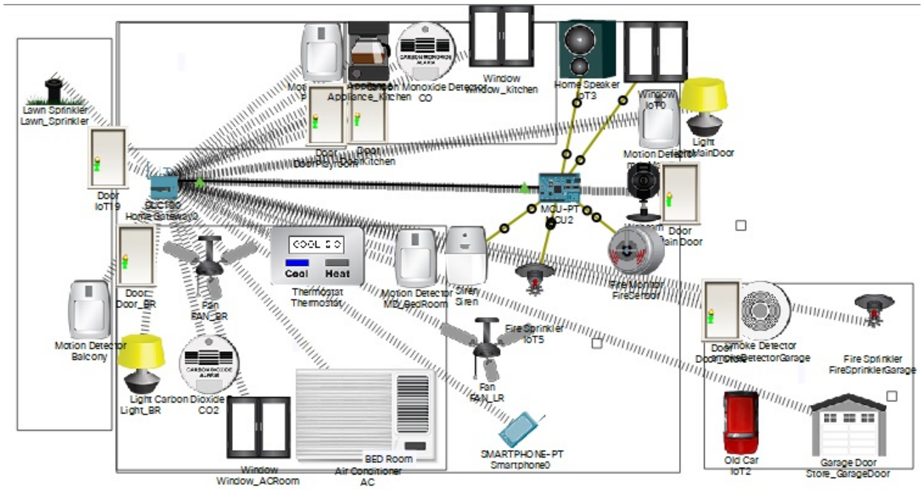

Figure 5: No Fire in Living Room

2.5 High level of Carbon dioxide (CO_2) is detected in bed room

2.5.1 Scene Specification

Home users are sleeping in the bed room and smart home observes high concentration level of CO_2 in the bed room.

2.5.2 Decision Making Logic

High concentration level CO_2 is harmful to human health and may have serious health consequences. The smart home as soon as detects the high concentration level of $C)_2$ which is a user defined parameter, it contains the situation and alerts the user.

2.5.3 Implementation and Result

In this scene following IoT equipment are deployed:

- A CO_2 detector
- Door and Windows
- Air Conditioner
- Smart Light
- Siren deplyed in living room

After sensing the higher concentration level of CO_2, the smart home initiates following action sequence:

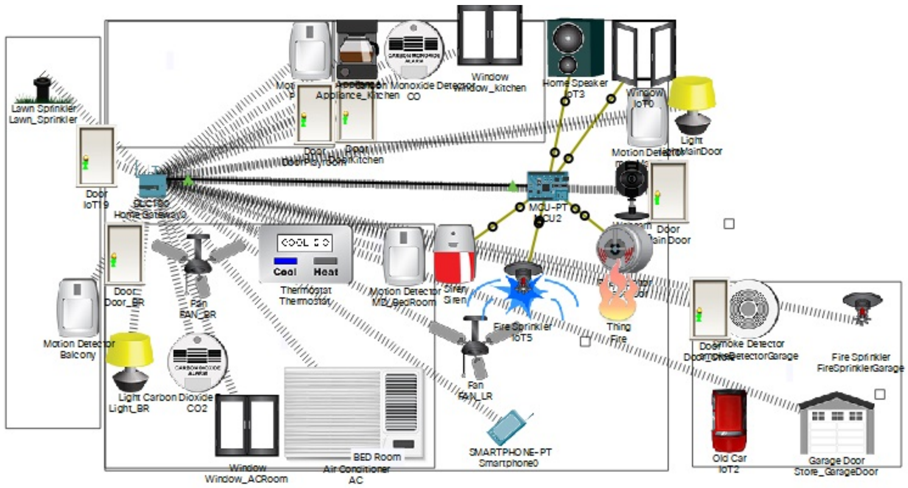

Figure 6: Fire in Living Room

- Open the Door and Windows of bed room
- Switch off the AC
- Set the FAN to the highest speed to disperse the high concentrated CO_2
- Switch On the bed room light
- Alert the user by activating the siren

Trigger if CO2 level goes high Open windows and doors Sound alarm

2.6 High level of Carbon Monoxide (CO) concentration is detected in Kitchen

2.6.1 Scene Specification

In this scene of smart home, the kitchen is operational and smart home senses that the concentration of CO has increased to a dangerous level.

2.6.2 Decision Making Logic

The CO is a harmful and dangerous gas if a person is exposed for a prolonged time. As soon as the smart home observes dangerous levels of CO in the kitchen, it alters the user and initiates mitigating actions

2.6.3 Implementation and Result

In this scene following IoT equipment are deployed:

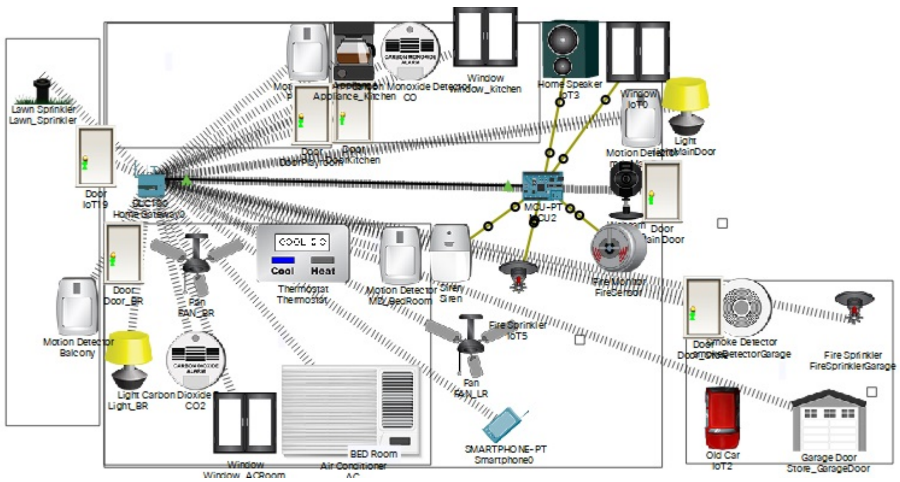

Figure 7: Store room no smoke

- A CO detector
- Kitchen appliance
- Siren of living room

After sensing the higher levels of CO, the smart home initiates following action sequence:

- Switch of the kitchen appliance
- Open windows and doors
- Sound alarm to alert the user

2.7 Room temperature rises

2.7.1 Scene Specification

The temperature of bed room varies, i.e. increases or then dips, the smart home needs to maintain a comfortable climate for users.

2.7.2 Decision Making Logic

When the room temperature rises then depending upon the temperature value appropriate action such as turning on FAN or air conditioning is done. If room temperature is comfortable then only FAN is switched on and if temperature further rises then AC is also engaged. Similarly, as the temperature decreases, appropriate actions is initiated by the smart home controller as per the pre-configuration done by user.

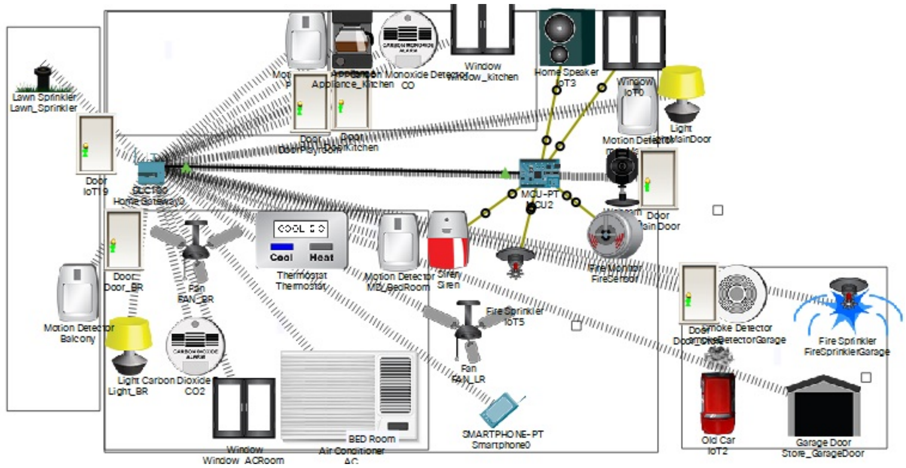

Figure 8: Store room with smoke detected

2.7.3 Implementation and Result

For temperature control in bed room following IoT equipment are used:

- Smart FAN
- Air Conditioner (AC)
- Thermostat : to measure the temperature

The action sequence is as following:

- If the room temperature rises above 18 °Celsius then the FAN is switched ON.
- If room temperature rises above 20 °Celsius then AC is also switched On
- If room temperature drops below 20 °Celsius then AC is switched Off
- If room temperature further drops below 18 °Celsius then FAN is switched Off
- If room temperature drops below 15 °Celsius then heating equipment is switched On.

3 Manual Commands

The IoT equipment emulated using CISCO packet tracer can be manually operated by accessing individual device in the layout or through the IoT monitor utility.

3.1 Accessing IoT equipment through Layout

User can manually access individual IoT device using the mouse in the CISCO Packet Tracer framework. The state of IoT device can be changed by selecting the respective device while keeping the ALT key pressed. This may also trigger a sequence of action if smart home is configured to act on chagned state of IoT device. The the figure, 9, shows that initially doors are closed and Car ignition of off, and user can manually open the doors and turn the ignition of engine on. We also observe that the smoke generated by the car triggers the smoke detector and is followed by a sequence of action by different IoT devices as per the configuration define by the user.

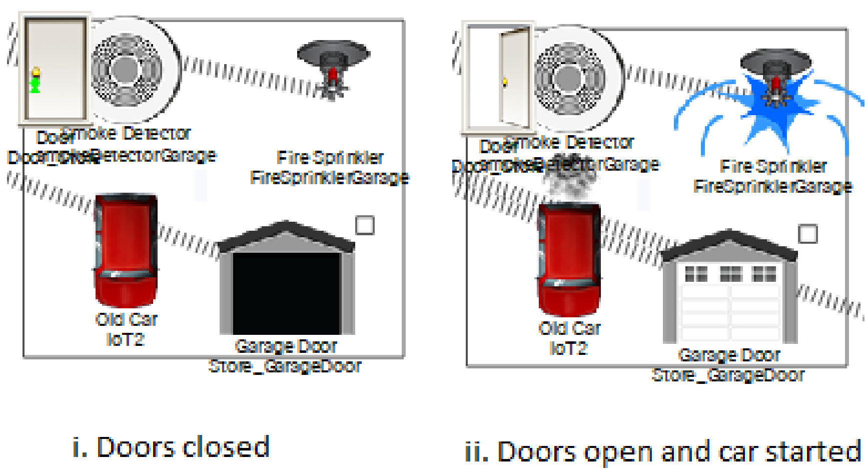

Figure 9: User Interface of Emulated Smart Home -I

3.2 Accessing IoT equipment through IoT Monitor

CISCO packet tracer framework facilitates access to the IoT equipment emulated in the experiment through a web interface or IoT controller which can be used to monitor and control them. The access to this portal is protected by user login credentials and only an authorized user can can login and control the deployed IoT equipment.

It may be noted in figure 10 that IoT equipment are listed and there functionalities can be controlled through the facilitated user interface.

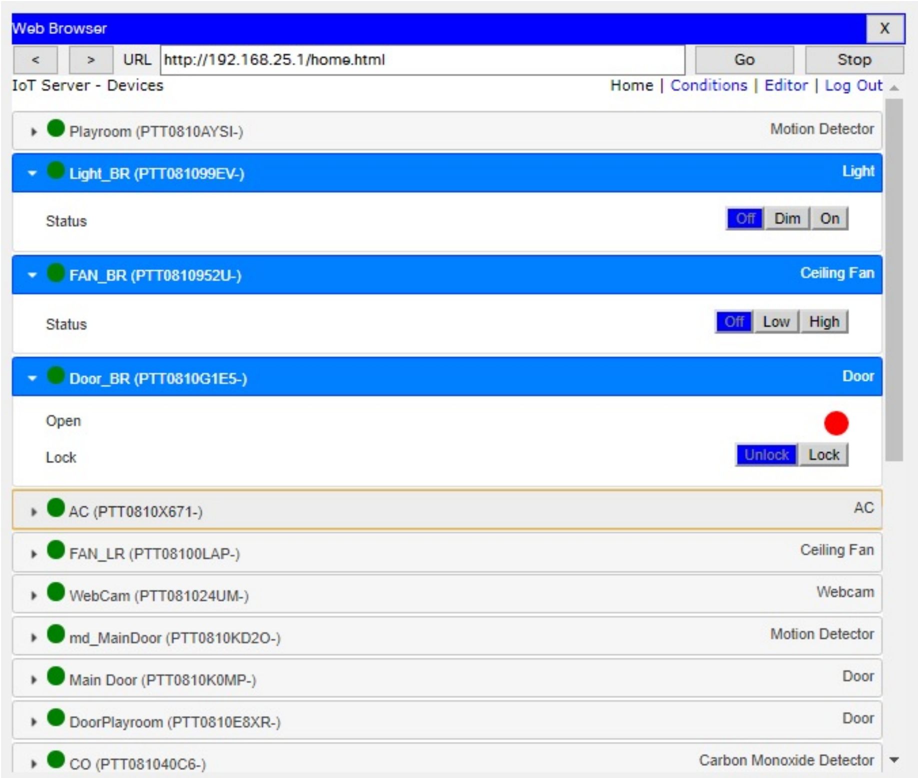

Figure 10: User Interface of Emulated Smart Home -II

4 Protocols and Security

4.1 Communication Protocols

The CISCO packet tracer facilitates to configure the environment to use various protocols such as MQTT, HTTPS, *etc.*, for communication among smart devices.

4.1.1 Message Queuing Telemetry Transport (MQTT)

MQTT protocol is based on publish and subscribe model and was created by Andy Standford-Clark and Arlen Nipper. This model is a simple model that provides support for QoS (Quality of Service). It is a popular protocol and can be found in every second IoT based device. This protocol has many features as it is over TCP(Transmission Control Protocol) and uses SSLTLS for security. For messaging between server it uses CONNECT, PUBLISH, SUBSCRIBE, DISCONNECT, etc.[1]

[1]Reference:https://www.geeksforgeeks.org/difference-between-mqtt-and-http-protocols/

4.1.2 Hyper Text Transfer Protocol (HTTP)

HTTP was developed by Tim Berners-Lee and is used for defining messages and their format in the World Wide Web (WWW). HTTP protocol is responsible for the action that a server has to take while sending information over the network. When a URL is being entered into the browser, this protocol sends an HTTP request to the server and then an HTTP response is sent back to the browser. This protocol is also responsible for the controlling of webpages on the World Wide Web for their formatting and representation.

4.1.3 Constrained Application Protocol (COAP)

The COAP is a client server-based protocol in which the COAP packet can be shared between different client nodes commanded by the COAP server. The server is responsible to share the information depending upon its logic but has not to acknowledge.

4.1.4 Advanced Message Queuing Protocol (AMQP)

AMQP protocol, developed by JP Morgan Chase, is used for communication between applications. It is a lightweight, protocol which supports the applications for transfer of data. It has asynchronous mode of communication and is used for its scalability and modularity with the technologies. It is easy to setup and manage, and has guaranteed message delivery. It provides publish and subscrive interface and can bear sever broke issue on its own. AMQP has message segmentation property, and it is fast, flexible and cost effective protocol. AQMP is usually used for client server applications communication.

4.2 Comparison of protocols used for IoT communication

S. No.	MQTT	HTTP	COAP
1	MQTT is architected based on publish and subscribe model	HTTP is based on request and response model	It uses request and response model
2	MQTT is a simple protocol and uses only asynchronous messaging mode.	HTTP is a synchronous protocol	Supports synchronous and asynchronous messaging modes
3	It runs over TCP	HTTP can run over, *i.e.* TCP and UDP	Primarily runs over UDP
4	MQTT is designed as data centric protocol.	HTTP design in document centric	It adds laberls to messages and does not provide persistence support
5	It has a header of 2 bytes	It has a header of 8 bytes	It has a 4 byte header
6	Users port 1883 and does not user REST principles	Default ports are 80 and 8080	It uses REST principles.
7	It provides data security with SSL/TLS.	It does not provide security.	COAP is used for Utility area Network and has secured mechanism

4.3 Selecting a Communication Protocol

It is important that the functional requirements of an IoT enabled environment meet the capabilities of resource-constrained devices. While selecting a communication protocol for the experiment it is assessed whether the selected protocol will work efficiently with IoT equipment identified for the deployment and non-functional requirement such as performance, scalability, compatibility with service provicers *etc.* will meet.

Literature survey that compares response time over one connection cycle for MQTT, shows that the initial connection setup increases the response time for sending single messages to the level that equals the response time of sending a single message over HTTP. The real advantage of MQTT over HTTP occurs when a single connection is reused for sending multiple messages.In essence when choosing MQTT over HTTP, it's really important to reuse the same connection as much as possible. If connections are set up and torn down frequently just to send individual messages, the efficiency gains are not significant compared to

HTTP.

4.4 Security

4.5 User Authentication

The IoT equipment deployed in smart home can be accessed using the controller available to users in their smart phone or tablet. However, to ensure these equipment are not controlled by an adversary, the login to the controller portal is controlled by user authentication. Only after a successful password based authentication, a user can operate or give any legal command to the IoT in the smart home.

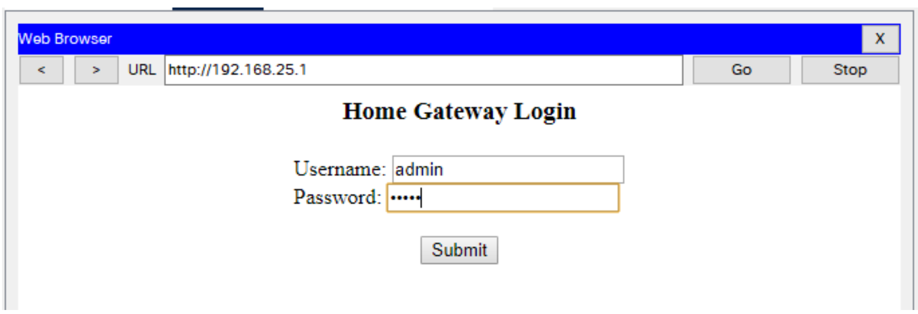

Figure 11: User Authentication to Access IoT Monitor

Figure 11 shows the user authentication window to access IoT monitor of smart home.

4.6 IoT Equipment Authentication and Integrity

IoT devices are connected using wireless WPA2-PSK which requires knowledge of pre-shared key between IoT devices and smart home gateway. Any IoT equipment which intends to be a part of smart home ecosystem needs to know the pre-shared key. The knowledge of pre-shared key between two parties in a control environment establishes mutual authentication, as shown in figure 12.

Further, MQTT runs over SSL/TLS to meet the security required of data in motion. TLS ensured that integrity of data in motion.

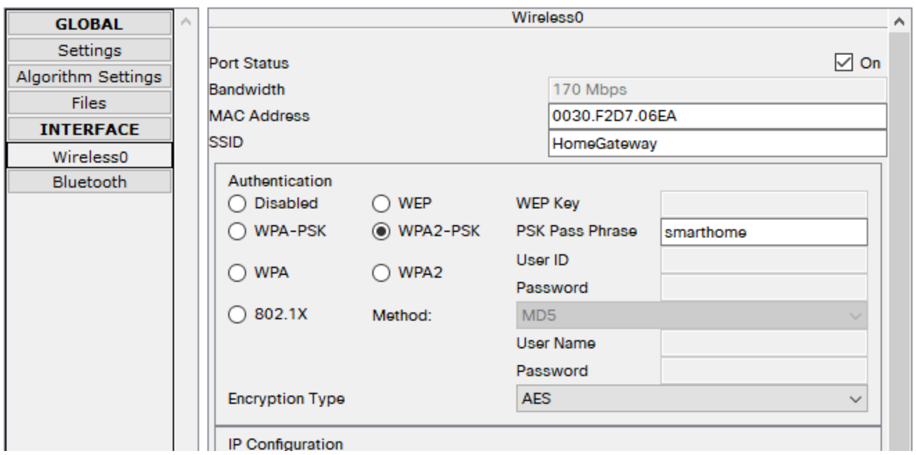

Figure 12: IoT Wireless WPA-PSK Security Setup