Design and Implementation of Efficient Network for IoT connected devices in Smart City using Cisco Packet Tracer

Report submitted to SASTRA Deemed to be University as the requirement of the course

CSE302: COMPUTER NETWORKS

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Project Based Work *Viva Voce* held on December 2022

Examiner 1 Examiner 2

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Abbreviations

IoT – Internet of Things

DNS – Domain Name System

DHCP – Dynamic Host Configuration Protocol

MQTT – Message Queuing Telemetry Transport

HTTP – Hyper Text Transfer Protocol

UDP – User Datagram Protocol

Abstract

IoT – Internet of Things – is a system of interconnected devices in the internet which can collect and transfer data without any human interference. This article reviews various aspects of a smart city, such as a smart home that monitors temperature in accordance with the environment, a smart garden that dispenses water in accordance with a water lever, and a smart grid that transfers energy from solar panels to power meters that charge batteries and assist in lighting bulbs. Modern urban ideas like "smart cities" are crucial for a high standard of living. The idea of smart cities is still not widely held worldwide due to high-tech, rational, and controllable barriers. The size, diversity, and configuration of devices allow for innovative services and frameworks that call for a fresh perspective on data management, integration, and reliability.

Keywords: Internet of Things, IoT, Smart City, Smart Parking, Smart Home, Smart Lawn, Cisco Packet Tracer

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Chapter 1: Introduction

IoT, abbreviated as Internet of Things, describes the network of physical objects. The term "Things" can refer to items that have sensors, software, and other technologies built into them so they can link to other devices and systems online and exchange data with them. Experts predict that the number of IoT devices will grow to 22 billion by the year 2025. Many industries employ IoT solutions to function more efficiently and it helps in better understanding of the customers' perspective, and improves the decision-making and increases the quality of business.

How does IoT work?

IoT system works through real-time collection and exchange of data. An IoT system vaguely consists of three components:

1. Smart Devices

   This can be anything like a personal computer, security camera, sensor or any equipment with the capability of computing, collecting or processing data. These smart devices collect data from the surrounding environment, inputs from the user, the usage patterns and it communicates these collected data over the internet to and from its IoT application.

2. IoT Application

   An IoT application receives the data communicated from the smart devices, consequently analyzes and processes the data using advanced technologies like Artificial Intelligence (AI) or Machine Learning (ML) and makes informed decisions.

3. A Graphical User Interface

   It is used to manage multiple interconnected IoT devices. Some common examples include website or a mobile application that can be used to monitor, register, log in or even control smart devices.

How can IoT make our lives better?

The impact of the Internet of Things on daily life and employment is extensive. It enables machines to perform more strenuous labor, take over boring activities, and improve the health, productivity, and comfort of life. For instance, connected devices might completely alter your morning routine. Your alarm clock would switch on the coffee maker and open the window blinds when you pressed the snooze button. When you have finished your groceries, your refrigerator will automatically order them for delivery. Your smart oven would inform you of the daily menu and may even provide reassembled items for your lunch. As your linked automobile automatically instructs the GPS to stop for a fuel refill, your smartwatch will book meetings. In an IoT world, there are countless chances!

Examples of IoT devices:

1. Smart City:

   Infrastructure upkeep and urban planning have become more effective thanks to IoT applications. IoT applications are being used by governments to address issues with infrastructure, health, and the environment. Applications for IoT include:

   - Air quality and radiation level monitoring systems

- Using smart lighting systems and energy harvesting systems to reduce electricity bills and to reduce less usage of fossil fuels
- Identifying the need for repair on crucial infrastructure, such as roads, bridges, and pipelines

2. Smart Homes:

Smart homes are targeted to improve the safety, networking and efficient use of available resources. IoT sensors can monitor and assist us in controlling various parameters such as room temperature, water level in the lawn and even smoke detectors can also be used to detect Tobacco smoke. Smart door locks, integrated security cameras are some intelligent elements that can detect, prevent and alert threats to the homeowners.

Connected devices for the home can be used for:

- Turning off devices that are not being used
- Automating daily tasks like coffee making, lawn maintenance etc.
- Regulating room temperatures

Software used:

Cisco Packet Tracer:

Packet Tracer is a free network simulator tool for certification exam preparation, particularly for CCNA students. It's available directly through the Cisco Networking Academy. Download and install the Packet Tracer software by signing up for the Introduction to Packet Tracer course, which teaches you the basics of using the tool (Cisco, n.d.).

Chapter 2: Design and Implementation

Smart City:

The Smart City is designed in such a way that there is always an interconnection between the submodule and Smart Control Office. This is done to ensure that the city is always being watched through and is at any time ready to be assisted in case of any emergency. This also helps in communication between various nodes about their states and parameters which in-turn facilitates smooth operation of the city. The Smart City in the project consist of five sub-modules namely:

- Smart Home
- Smart Control Office
- Smart Parking
- Smart Traffic Control
- ISP Main (Internet Service Provider)

The Smart City also has a cellular tower established that provides Internet services to smartphones all over the city.

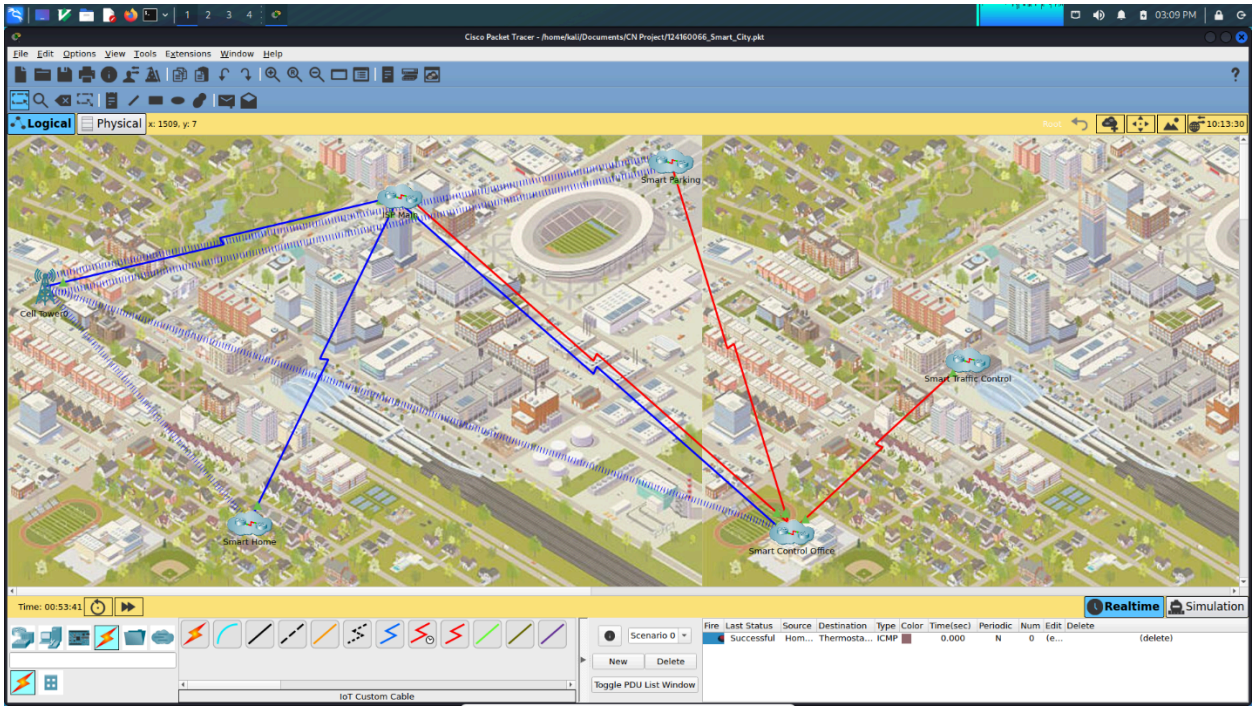


Fig. 1 Overall Network

1. <u>ISP Main (Internet Service Provider):</u>

The ISP Main Cluster comprises the heart of the Smart City. It comprises of a Server, Cloud and a Central Office Server that is connected to the Main Router present in the cluster. The Coaxial Splitter splits the data from the cloud and gives it to the City Control Monitor and Home Splitter. The Cellular Network is also connected to the Central Office Server to share the cellular connection. The Main Router is connected to the City Control Router such that all the data is being shared at a higher level and the communication is on full swing all the time. The Server has DHCP configured so that the connected devices can automatically receive IP address. Also, DNS has been configured to enable redirection of URLs to destination IP addresses.

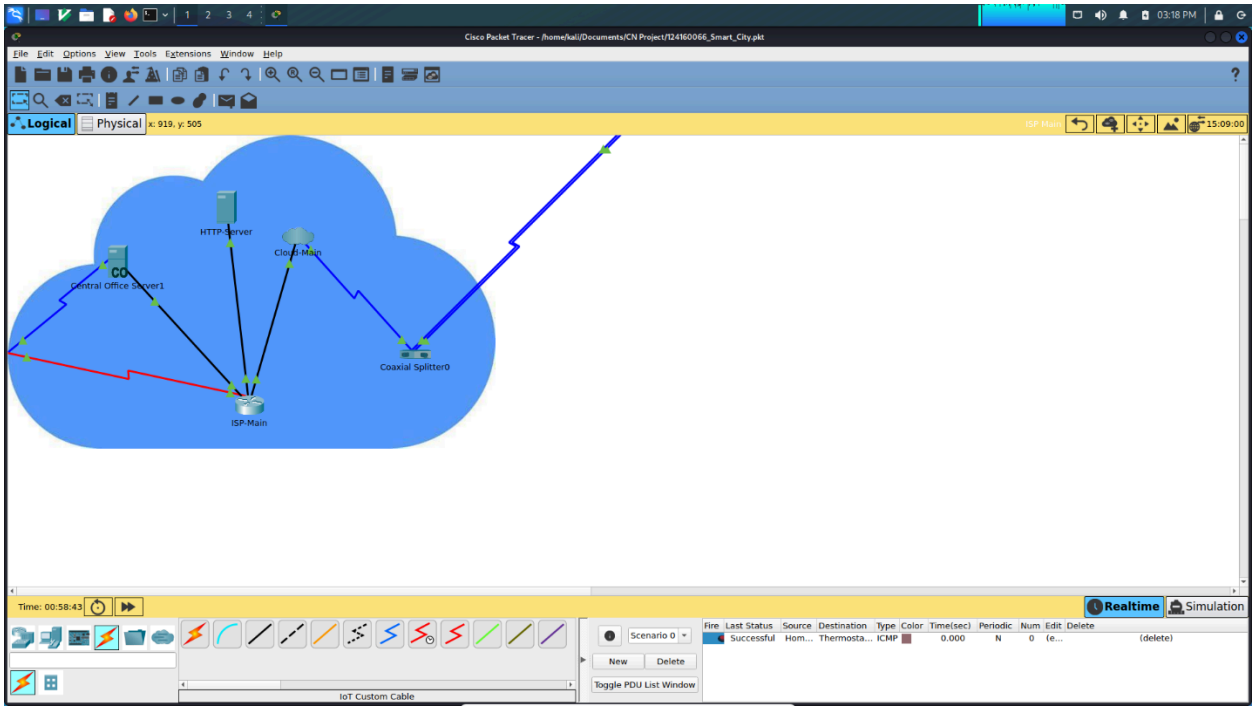


Fig. 2 ISP Main Cluster

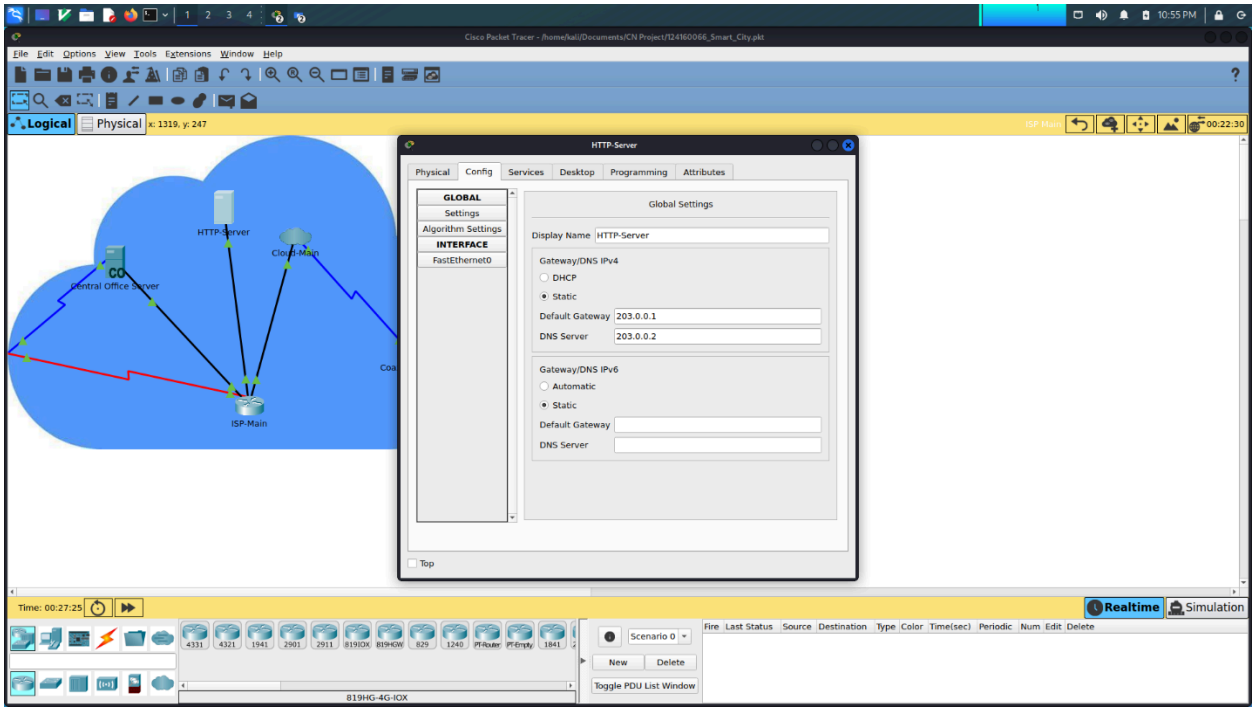


Fig. 3 Server Default gateway and DNS server configuration

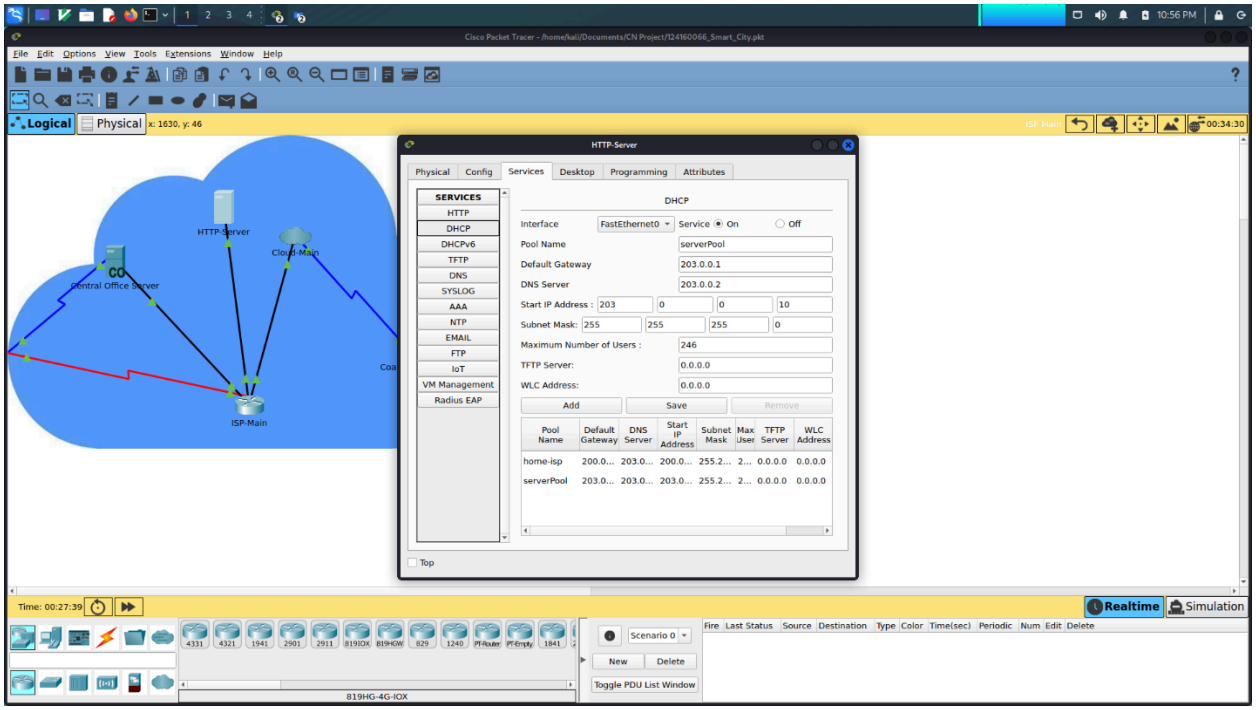


Fig. 4 Server DHCP configuration

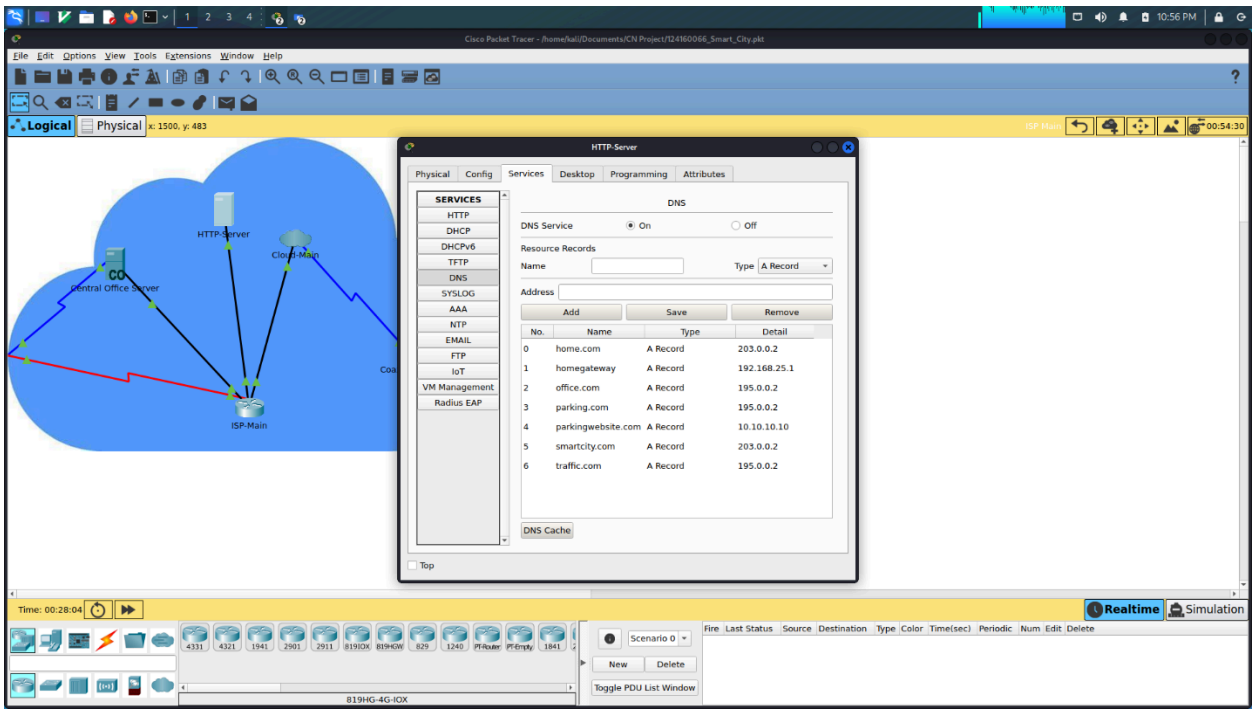
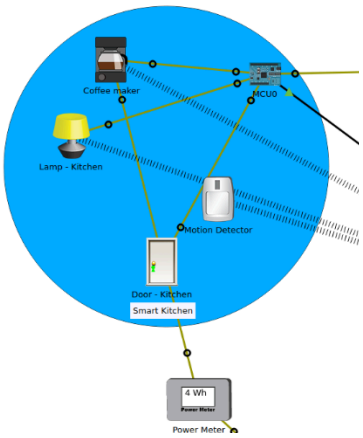


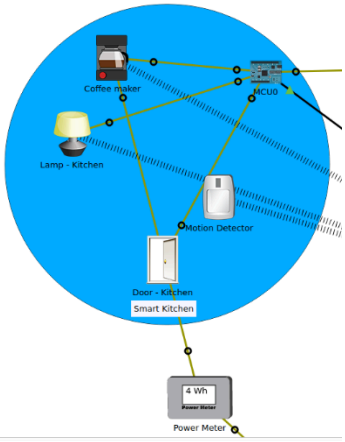
Fig. 5 Server DNS configuration

2. Smart Home:

Smart Home consists of various IoT sensors and actuators that helps one in controlling parameters such as room temperature, automating everyday tasks like making coffee, watering lawn etc., can also be used to monitor and alert upon any intrusion. The Smart Home design here consists of very selected applications among the above listed ones. It comprises of a

- Smart Kitchen

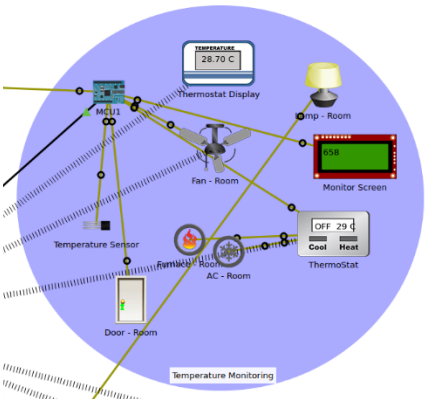




Smart Kitchen comprises of a Smart Lamp, a Coffee Maker, a Motion detector and a Micro Controller Unit that works together to light up and start making coffee when one enters the kitchen and stop when the leave the kitchen. The Coffee Maker and Lamp-Kitchen can also be manually controlled via the Home Gateway without entering the kitchen. The Coffee Maker can also draw power from the energy stored in the batteries harvested from the Solar Panel.

Fig. 6 Off and On state of lights and coffee maker based on the door's state

- Temperature Monitoring System



It comprises of Thermostat display, a temperature sensor, a furnace and Air Conditioner, a Thermostat, a fan and a custom display that outputs the temperature as sensed by the temperature sensor and a micro controller unit. The Thermostat adjusts the room temperature making sure that the room temperature doesn't drop below 28°C and 30°C. When the Thermostat is in Off state (when the temperature is within the threshold), the microcontroller unit turns on the fan such that room temperature doesn't change instantaneously.

Fig. 7 Temperature Monitoring System

- Solar energy Harvesting circuit

This is a simple solar energy harvesting circuit comprising of multiple solar panels linked to various batteries. These batteries provide electricity to various elements in the Smart Home network.

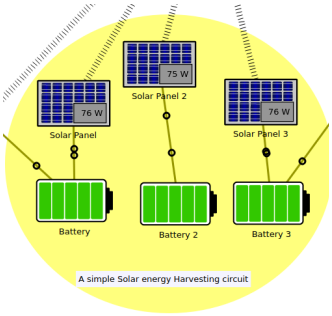
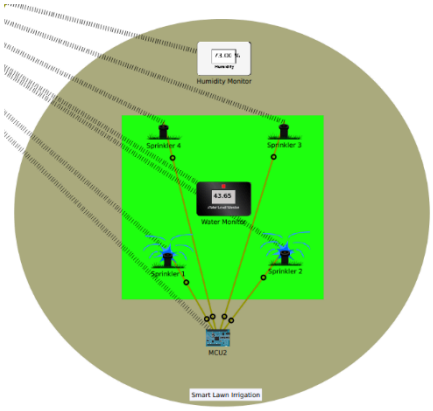


Fig. 8 Solar Energy Harvesting System

- Smart Lawn Irrigation System

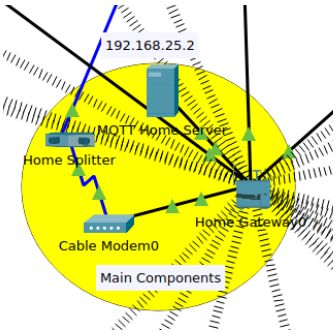


This comprises of Humidity Monitor, various sprinklers, water monitor and a micro controller unit. It takes care of the water level of the field and makes sure that the water level doesn't exceed the required level. These can also be

altered according to the needs and seasons and can also be controlled from the home gateway IoT server.

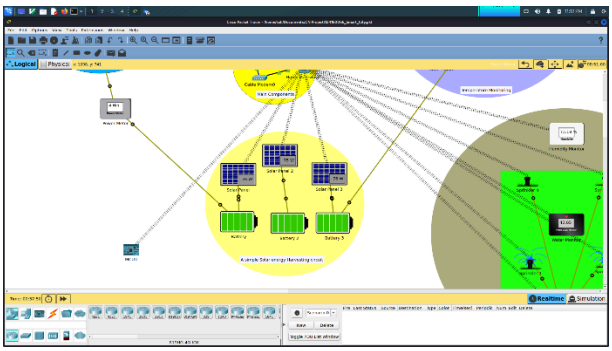
Fig. 9 Smart Lawn Irrigation

- Main Components



The main components cluster is a collection of all the important networking elements that facilitate such a smooth and operable connections in the smart home network. It also has a MQTT Home Server which acts as a MQTT broker in the network and facilitates MQTT connection in the Smart Home network.

Fig. 10 Main Components



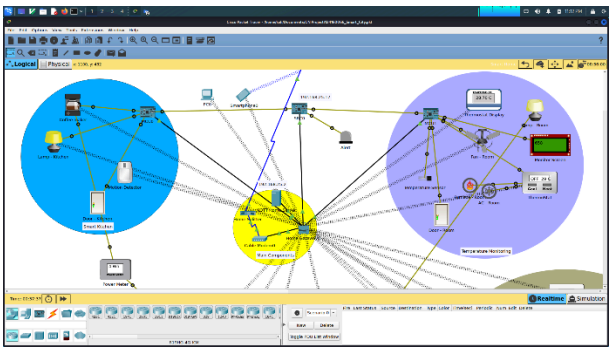


Fig. 11 Smart Home Network

- MQTT Broker and Client

The Smart Home has a MQTT server that acts as a MQTT broker. It runs on the IP '192.168.25.2'. All the end devices like Personal Computer, Smartphones runs MQTT Client on it with them subscribing to a specific topic. The single board computer presents which receives data from the micro controller units present in both smart kitchen and temperature monitoring system runs MQTT Client with it publishing values to a specific topic.

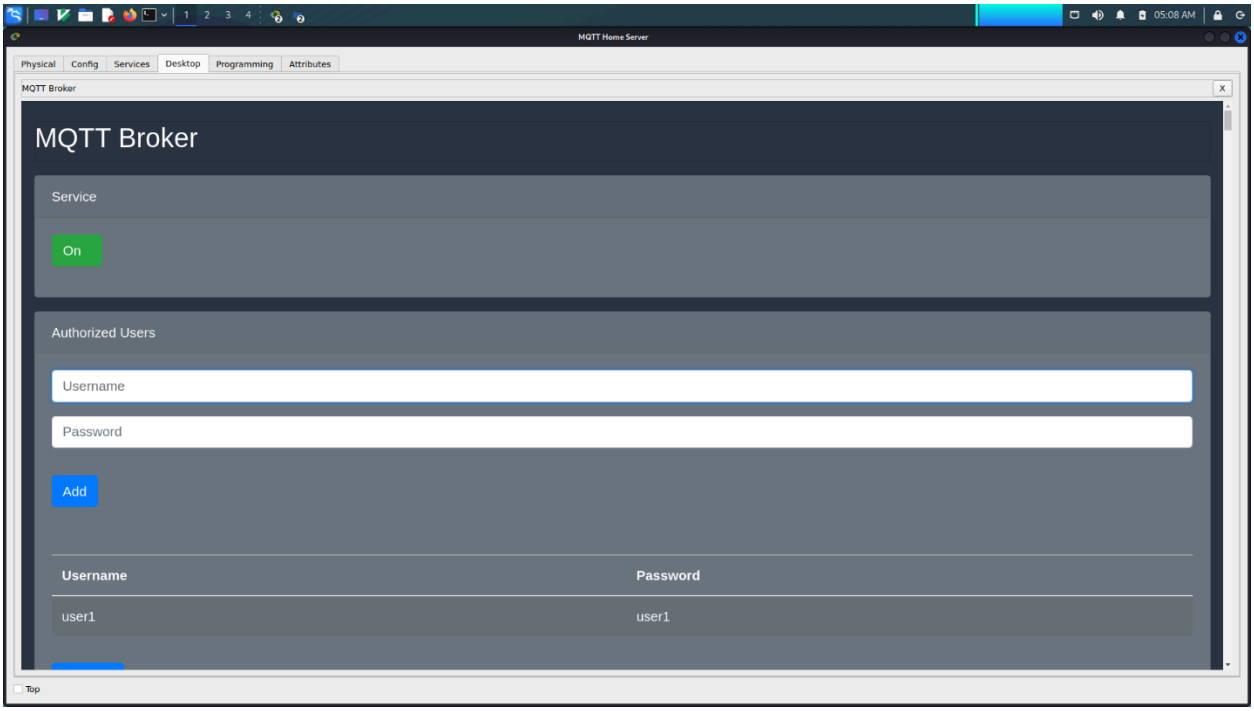
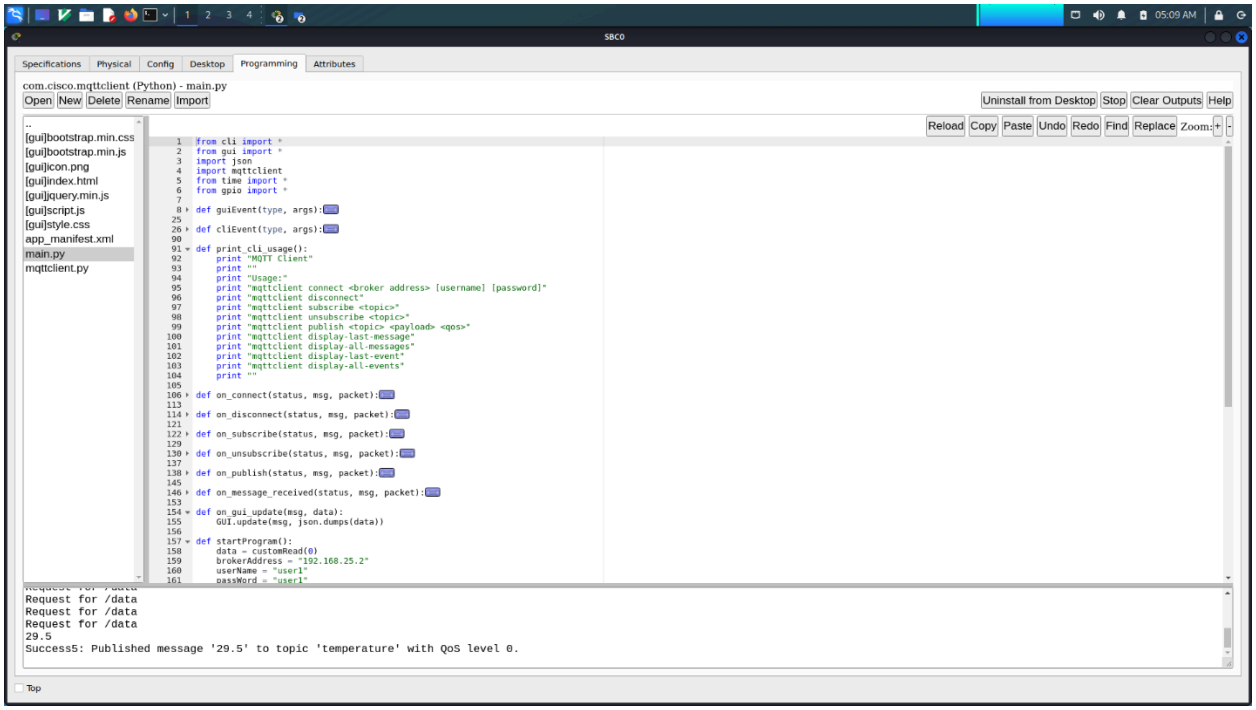


Fig. 12 MQTT Broker



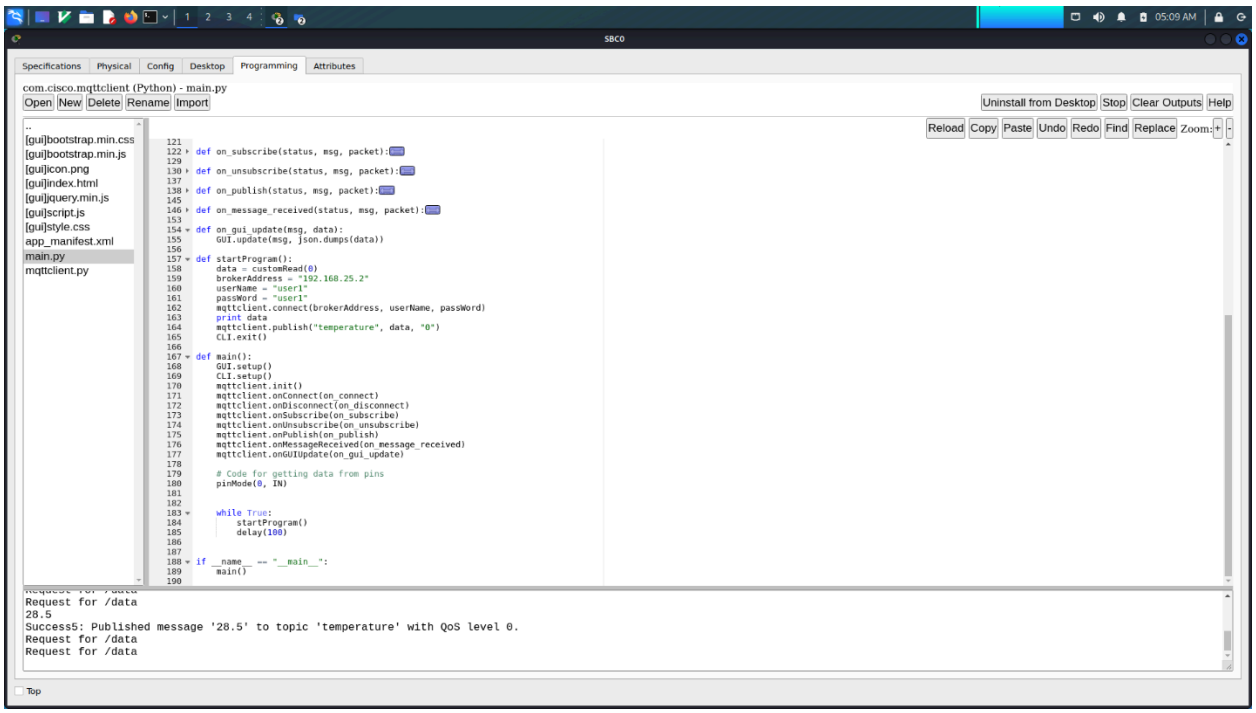
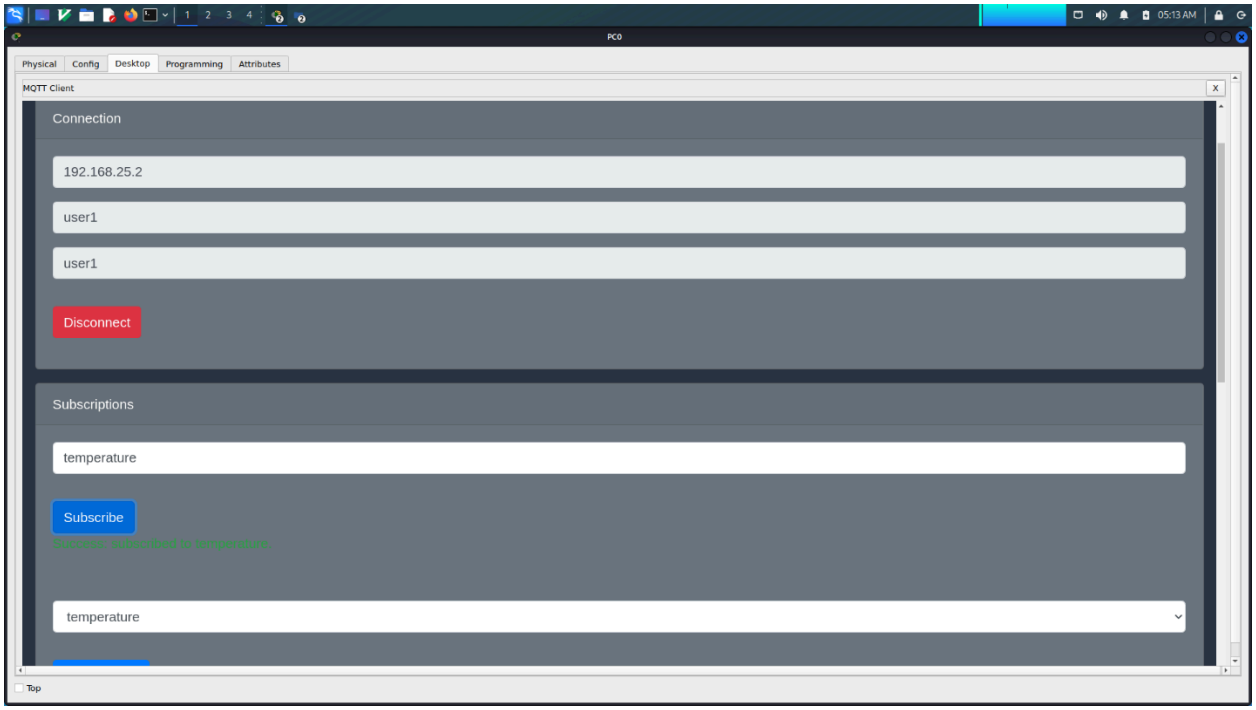


Fig. 13 & 14 MQTT Client Temperature Publisher



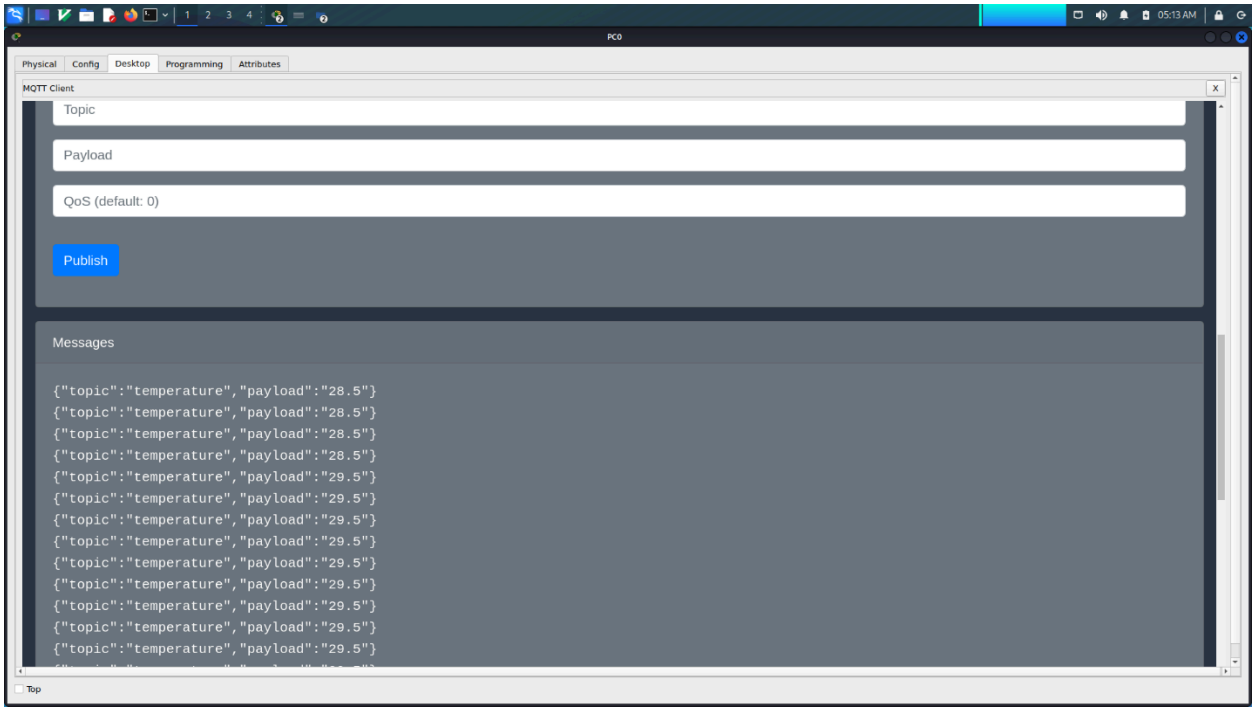


Fig. 15 & 16 MQTT Client Temperature Subscriber

3. Smart Control Office:

Smart Control Office acts as the brain of the smart city. The main router is connected to all other branches of the Smart City. The data from all the other clusters flow to the router in the city control so that data can be accessed from any cluster at any point of time. The Smart Control Office has a city IoT server, IT control laptop, City Control Monitor to look at CCTV footages, Office PCs, Reception PC, Police PC and access point. It also has a visitors' room where visitors have the freedom to control the window, fan and light using the IoT interconnection. The Smart Control Office also has an environment observation unit which monitors the level of carbon monoxide and carbon dioxide in the air of the smart city.

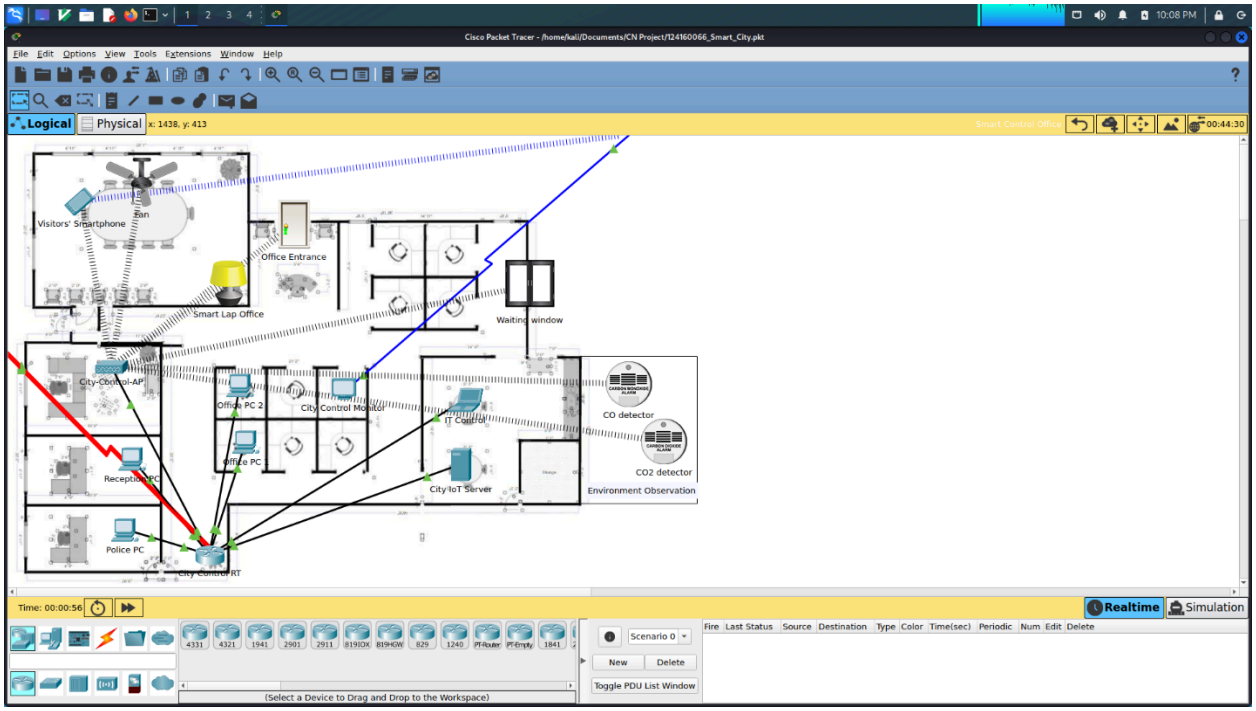


Fig. 17 Smart Control Office Network

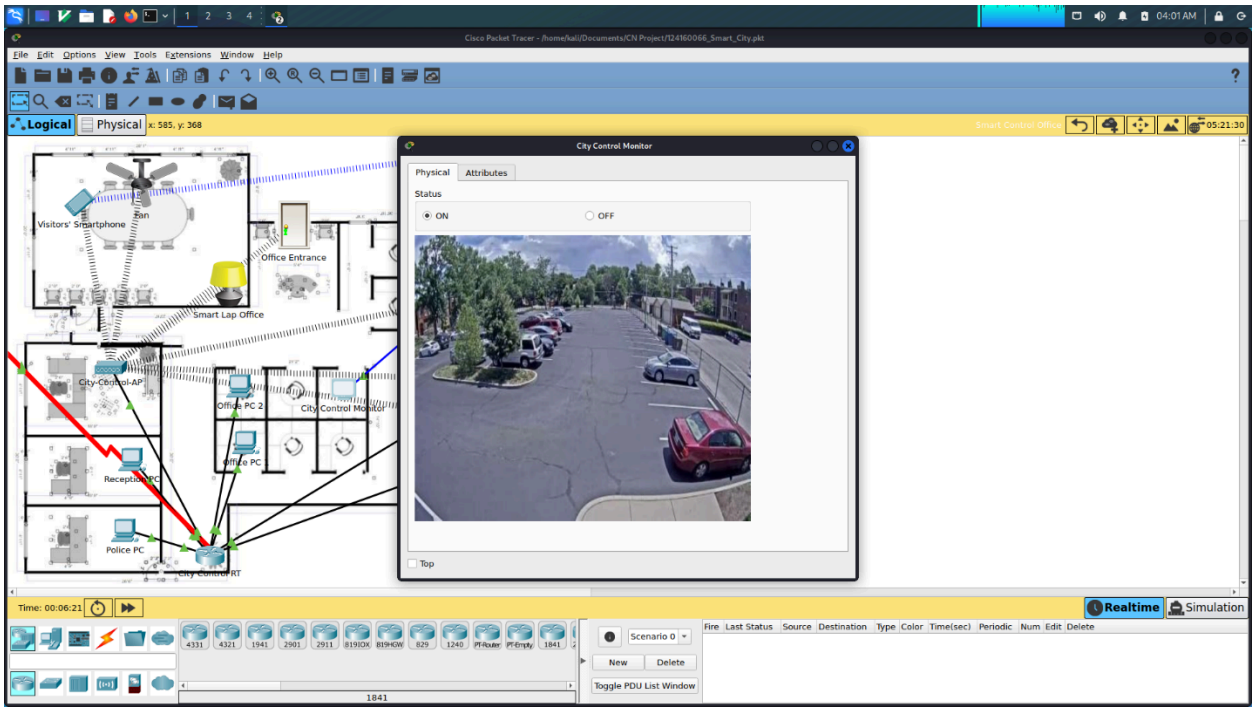


Fig. 18 City Control Monitor displaying recording from webcams

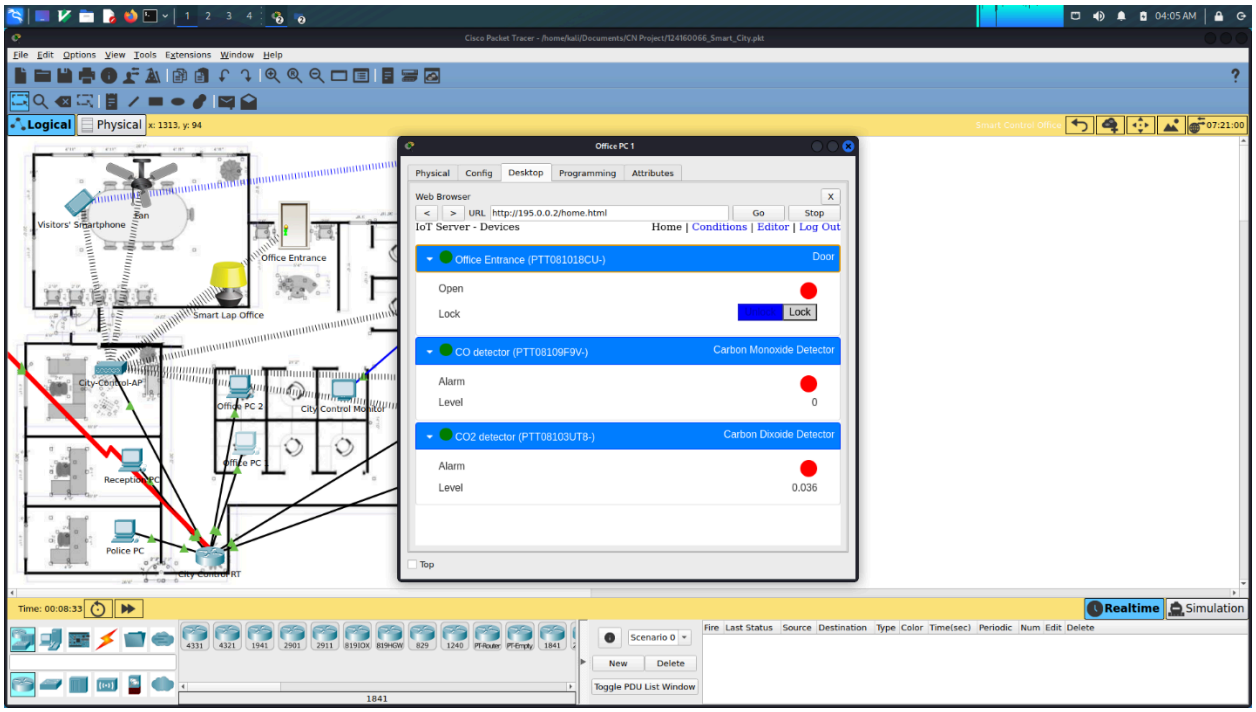


Fig. 19 Administrator panel for IoT monitoring in the Smart Control Office

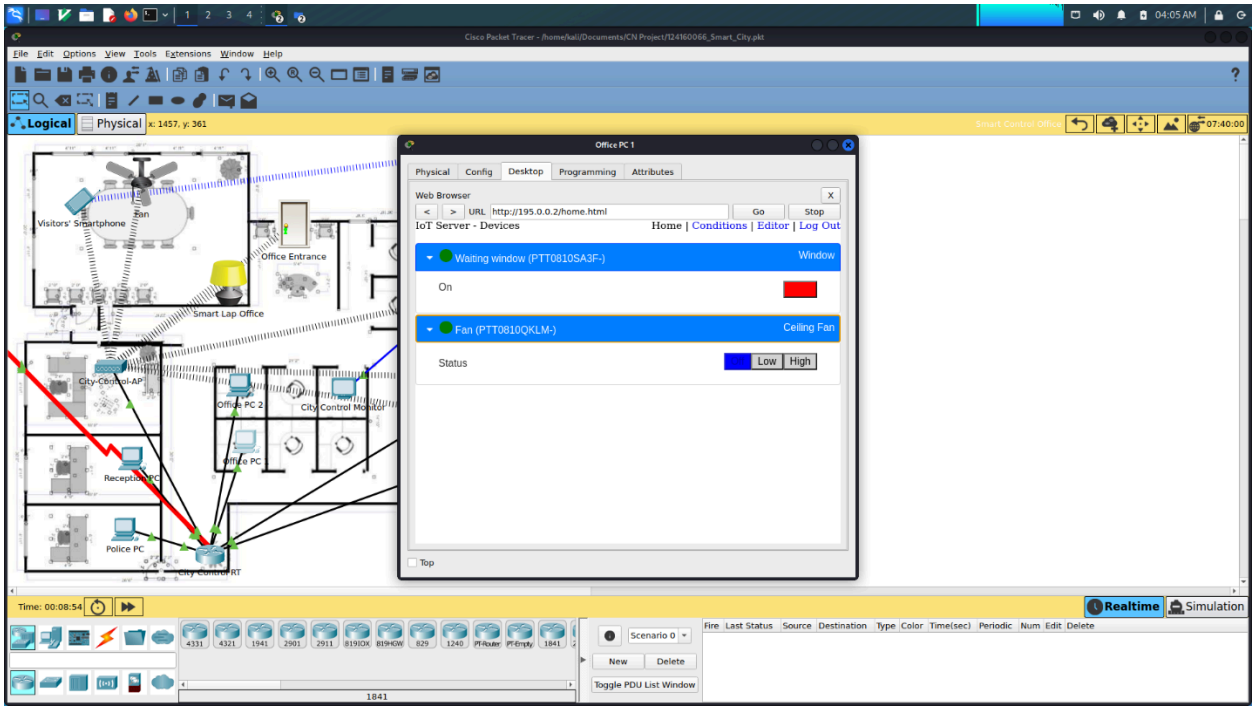


Fig. 20 Visitors' IoT Monitor Panel to control fans and lights and windows in the waiting room

4. Smart Traffic Control

Smart Traffic Control is designed in such a way that the traffic control in the city is well organized to not cause any jam and at the same facilitate any emergency and make sure that the emergency case is getting addressed. The network here consists of a simple Traffic Router that is connected to the router in the Smart Control Office to transmit all the data, a traffic access point to which all future small vehicles will be connected to and a micro controller unit. As the future smart vehicles will be connected to the access point, we can collect co-ordinates of the vehicle and keep a track of the position, motion and trajectory of the vehicle. The traffic lights can also potentially have cams with Computer Vision technology integrated to look for emergency vehicles and adjust the traffic accordingly.

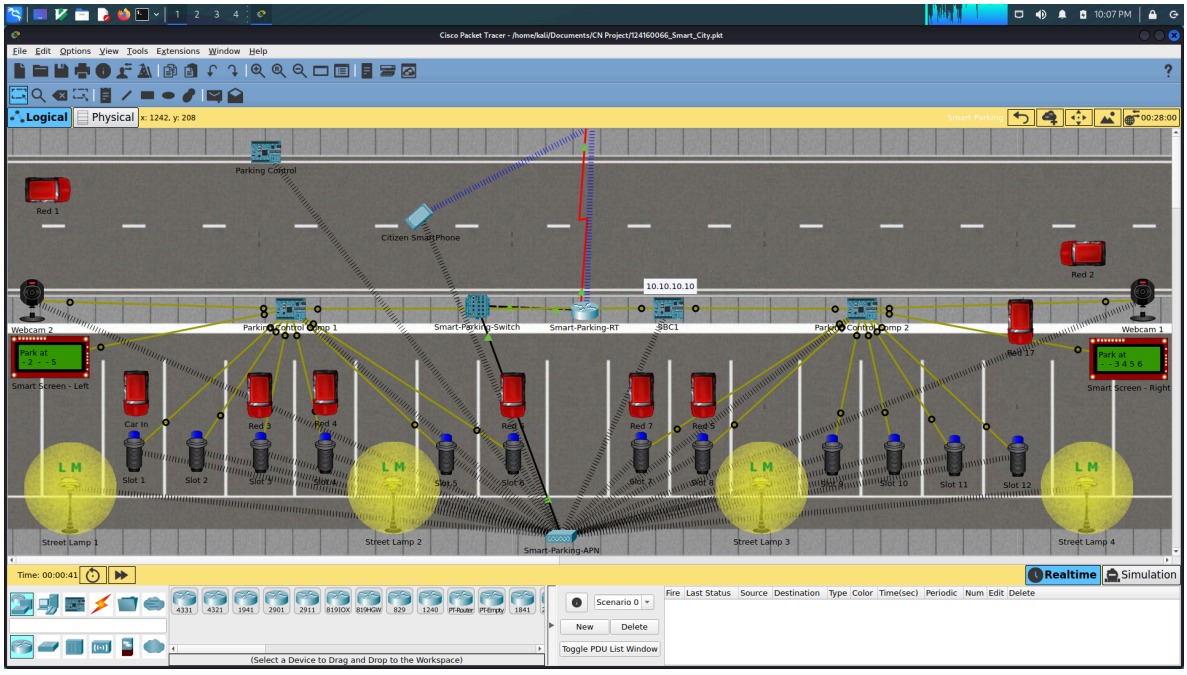
Fig. 21 Smart Traffic Network

In this case, the microcontroller unit collects the co-ordinates of the emergency vehicle and if the co-ordinates cross a certain threshold the traffic lights for all other lanes go **“**red” and the lane where the emergency vehicle is coming/travelling goes “green”.

Fig. 22 Regular Traffic

Fig. 23 & 24 Traffic Lights as the emergency vehicles approaches and leaves the intersection

5. Smart Parking:

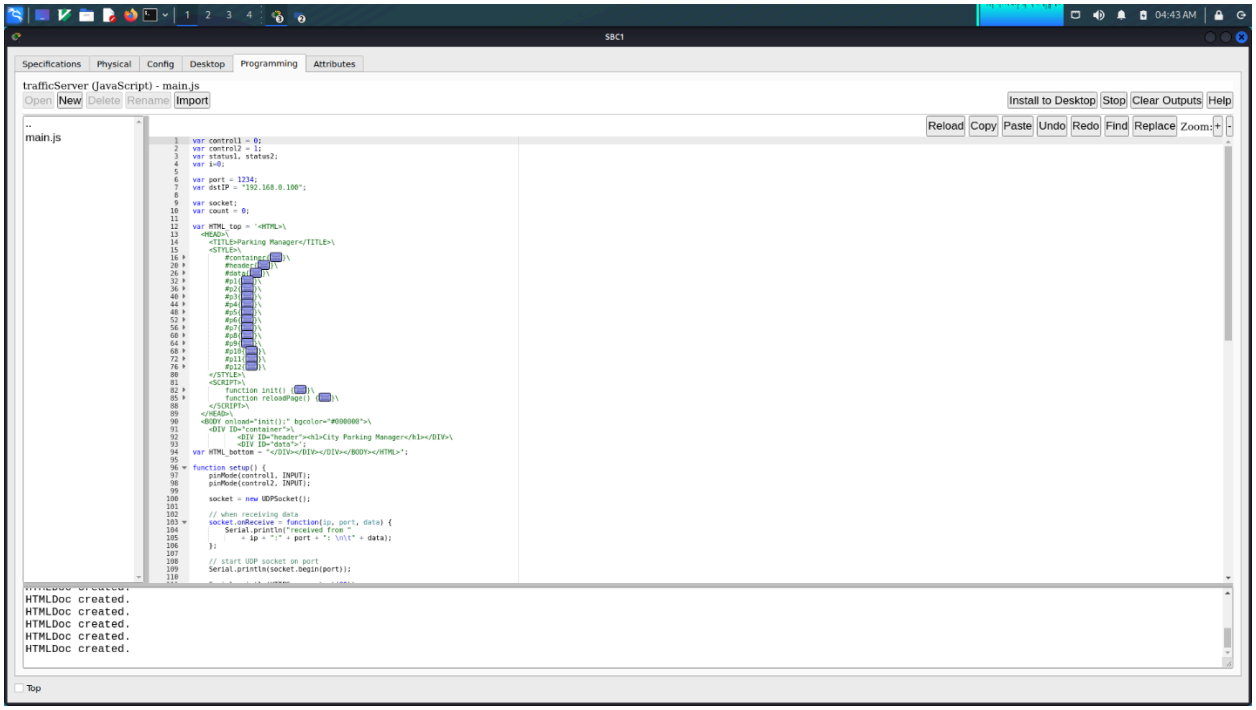


Smart Parking network consists of a Router, a Switch, multiple micro controller units and single board computer, street lamps, various alloy/metal detectors, webcams and displays. The metal sensors are linked with the microcontroller boards which receive the status of the sensors and then alter the display boards to display all the available and

taken position in the parking lot. This micro controller unit is linked to a single board computer which hosts a http server that runs on the computer and can be accessed from ‘http://10.10.10.10’. This will redirect the user to a website which displays all the parking spots with the information that they are available/taken. This helps the driver/smart citizen to be aware of where to park way ahead of him/her actually showing up to the lot. The display in the network represents a digital screen in the size of a billboard which will be places in the front of the parking lot to inform the smart citizens about the status of parking spots in the lot.

Fig. 25 Smart Parking network

Fig. 26 Smart Parking HTTP site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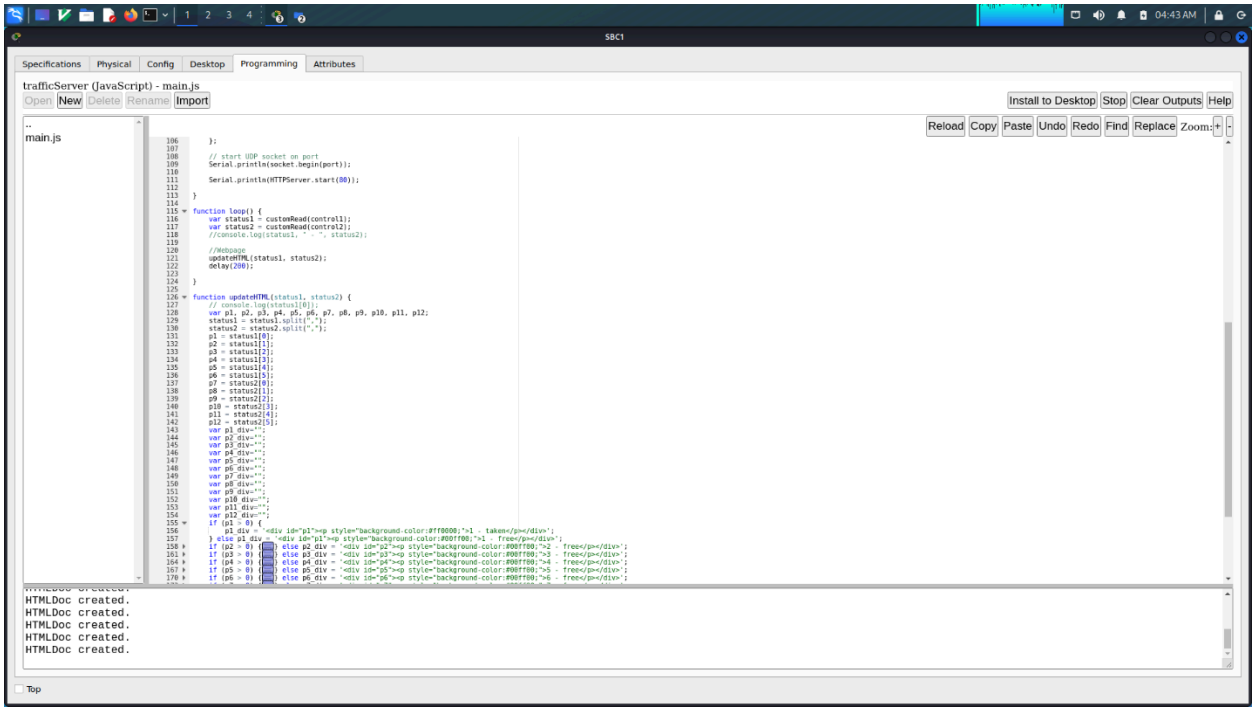
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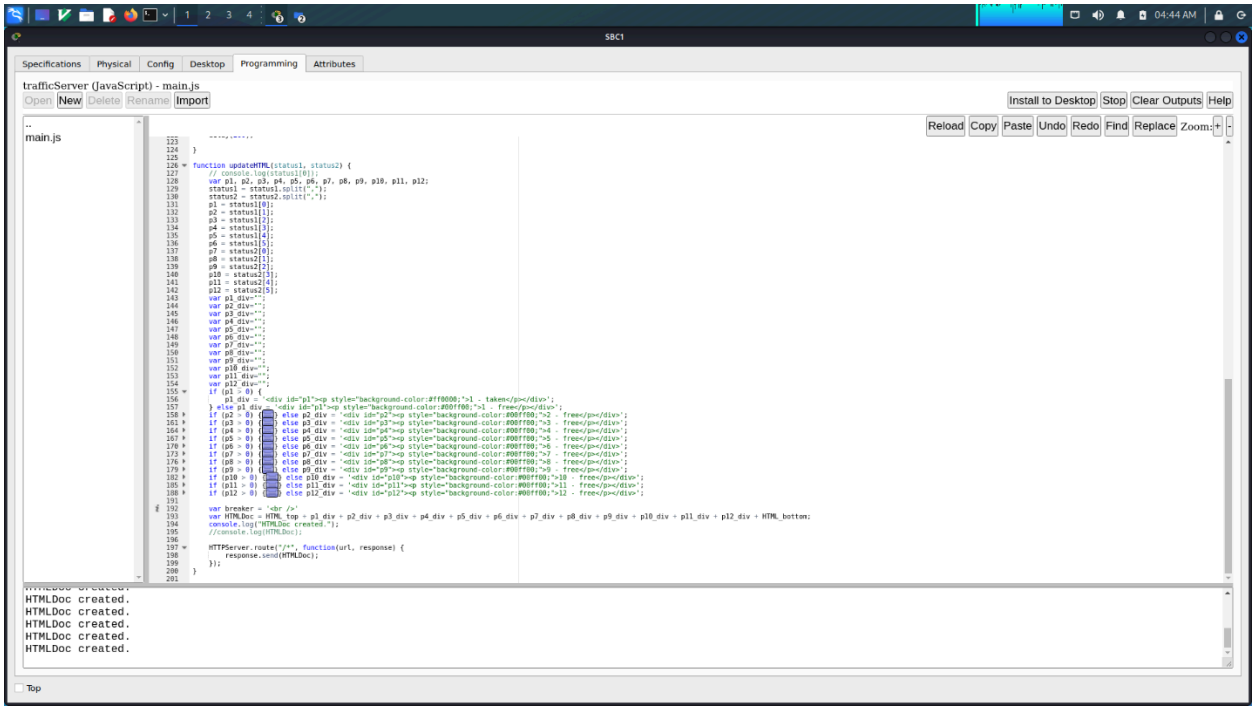

Fig. 27, 28 & 29 HTTP server code

Chapter 3: Conclusion and Future Plans

Conclusion:

IoT is more intricately linked to the broader social structure than it is to the massive technology. The development of a modern metropolis that makes people's lives easier is the goal of this study paper. The smart home, smart parking system, smart traffic, and smart parking were the main topics of focus in this paper. Some of the components of a smart city are described in detail in order to recognize the organizing principle. But we should also understand the practical difficulties faced in immediately implementing it. This also proves the fact that it will take many

years of research and constant refinement of designs to come to one final prototype design which can be implemented in the scale of a city.

Future Plans:

Smart City is not just about the above-mentioned submodules. There are still many submodules that have been left out smart hospitals, smart grid, smart police station, smart fire stations and many more. Also, all these modules can have a more organized medium of communication to share and utilize data amongst them, which can facilitate a central control of the whole city and thus satisfying the real motto of a “Smart City”.

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