University of Mohamed Khider -Biskra-
Faculty of Science and Technology
Department of Electrical Engineering

MASTER THESIS

Science and Technology

Telecommunication

Network and Telecommunication

Ref:

Presented and submitted by: **RAHMOUNI AHMED**

On: June 5th 2025

IoT BASED SMART IRRIGATION SYSTEM

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Presented By: RAHMOUNI Ahmed

Favorable opinion of supervisor: Dr. HAMAIZIA Zahra

Positive opinion of the President of the Jury

Mrs.	BARKAT Aicha	MAA	University of Biskra	President

STAMP AND SEGNATURE

DEDICATION

This thesis is dedicated to my beloved family, whose unwavering support and encouragement have been my greatest strength. To my friends and professors, thank you for your guidance and motivation throughout this journey. May this work inspire future research and innovations in smart agriculture.

Acknowledgments

I would like to express my gratitude to Pr. Hamaizia Zahra, my supervisor for her guidance, patience, and support through this research. Her expertise and encouragement have been instrumental in guiding the direction of this thesis.

I extend my sincere appreciation to my professors and mentors at the University of Mohamed Khider Biskra, whose knowledge and dedication have greatly enriched my academic journey. Special thanks go to the jury members for their time, feedback, and constructive evaluation of this work.

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Table OF Abbreviations

IoT : Internet of Things
WIFI : Wireless Fidelity
LoRaWAN : Long Range Wide Area Network
ESP : Event Stream Processing
SSID : Service Set Identifier
IP : Internet Protocol
DHCP : Dynamic Host Configuration Protocol
ISP : Internet Service Provider
PT : Public Transport
DNS : Domain Name System
MAC : Media Access Control
Fa : FastEthernet
Eth : Ethernet
Coax : Coaxial
CIDR : Classless Inter-Domain Routing
HG : Home Gateway
WR : Write Memory
WPA : Wi-Fi Protected Access
PSK : Phase-Shift Keying
AES : Advanced Encryption Standard
RFID : Radio Frequency Identification
NodeMCU : Node MicroController Unit
LCD : Liquid Crystal Display
I2C : Inter Integrated Circuit

Abstract

This work presents the development of an IoT-based smart irrigation system to optimize water usage in agriculture through automation and remote monitoring. A networked greenhouse system was simulated in Cisco Packet Tracer, integrating sensors, actuators, DNS, DHCP, and remote access for real-time control. A practical implementation using NodeMCU ESP8266, a soil moisture sensor, and Blynk demonstrated automated plant watering, reducing water waste and improving efficiency.

Keywords: *IoT, Smart Irrigation, Cisco Packet Tracer, NodeMCU ESP8266, Blynk Platform, DNS, DHCP, Wireless Communication, Soil Moisture Sensor.*

Résumé

Ce travaille porte sur le développement d’un système d’irrigation intelligent basé sur l’IoT pour optimiser l’utilisation de l’eau en agriculture grâce à l’automatisation et la surveillance à distance. Un système de serre connecté a été simulé sous Cisco Packet Tracer, intégrant des capteurs, des actionneurs, le DNS, le DHCP et l’accès à distance pour un contrôle en temps réel. Une implémentation pratique avec NodeMCU ESP8266, un capteur d’humidité du sol et Blynk a démontré un système d’arrosage automatisé, réduisant le gaspillage d’eau tout en améliorant l’efficacité.

Mots-clés: *IoT, Irrigation Intelligente, Cisco Packet Tracer, NodeMCU ESP8266, Plateforme Blynk, DNS, DHCP, Communication Sans Fil, Capteur d’Humidité du Sol.*

الملخص

يقدم هذا العمل تطوير نظام ري ذكي قائم على إنترنت الأشياء لتحسين استخدام المياه في الزراعة من خلال الأتمتة (التحكم الالي) والمراقبة عن بُعد. تمت محاكاة نظام دفيئة شبكي باستخدام برنامج Cisco Packet Tracer، حيث تم دمج أجهزة الاستشعار والمشغلات ونظامي DNS وDHCP والوصول عن بُعد للتحكم الفوري. أظهر تطبيق عملي باستخدام NodeMCU ESP8266، وهو مستشعر رطوبة التربة، وBlynk، أتمتة ري النباتات، مما يقلل من هدر المياه ويحسن الكفاءة.

الكلمات المفتاحية: إنترنت الأشياء، الري الذكي، Cisco Packet Tracer، NodeMCU ESP8266، مراقبة البيوت البلاستيكية، منصة Blynk، DNS، DHCP، الاتصالات اللاسلكية، مستشعر رطوبة التربة.

GENERAL INTRODUCTION

General Introduction:

Blue gold (Water) is the essence of life but also therefor it is the backbone of agriculture. With the global population projected to approach 9 billion by mid-century and climate change intensifying its impacts. The insurance of sufficient food production under constrained and increasingly erratic water supplies has become a paramount challenge. Agriculture consumes nearly 70% of the world's freshwater, yet many of the irrigation practices in use today, some of which date back centuries, suffer from critical inefficiencies losses due to evaporation, runoff, and uneven distribution are commonplace, especially in arid and semi-arid regions.

Recent advancements in the Internet of Things (IoT) have paved the way for smarter and more efficient water management systems. IoT-based smart irrigation systems integrate real-time sensing, automated control and sophisticated data analytics to deliver water precisely when and where it is needed. By deploying cost-effective microcontrollers such as the Arduino Uno, Arduino Mega, and ESP8266/ESP32, in conjunction with robust sensor networks and wireless communication protocols (e.g., WIFI, LoRaWAN), these systems are capable of reducing water waste and energy consumption while simultaneously maximizing crop yields. The integration of cloud computing and mobile interfaces through platforms like Blynk and RemoteXY for further empowers farmers with remote monitoring and control capabilities.

The objective of this thesis is to design, implement and evaluate a cutting-edge IoT-based smart irrigation system that addresses both the technical challenges of precision water management and the broader socio-economic and environmental impacts of water scarcity. This work aims to advance sustainable agriculture by reducing water consumption and boosting crop productivity while ensuring that the system is robust, scalable, and adaptive to real-world conditions.

This thesis is divided into three main chapters:

Chapter 1: Generalities on Irrigation Systems

Chapter 2: IoT Based Smart Irrigation Monitoring System using Cisco Packet Tracer

Chapter 3: IoT Plant watering system using ESP8266 and Blynk

The thesis concludes with a general conclusion, outlook, and references.

CHAPTER I

Generalities On Irrigation Systems

I.1 Introduction

Irrigation, defined as the artificial application of water to soil for agricultural purposes, has been practiced since ancient times. Early civilizations relied on manual methods and gravity-fed systems to distribute water, but these methods were limited by labor intensity and natural variability. Over the centuries, irrigation has evolved through various stages from rudimentary flood and basin systems to modern pressurized, automated methods. Despite these advances, many conventional techniques still suffer from inefficiencies that lead to significant water losses. In today's context, the twin challenges of climate variability and rapid population growth have underscored the need for a radical rethinking of irrigation practices [1].

This chapter provides a detailed overview of irrigation technologies, examining the evolution of techniques and highlighting the critical issues arising from water mismanagement. It also situates these discussions within the framework of the global water crisis, thereby establishing the context for the adoption of IoT-based smart irrigation systems.

I.2 Importance of Efficient Irrigation

Water is fundamental to the biochemical processes of plants; its efficient management is pivotal for crop productivity and food security. Efficient irrigation has several interlinked benefits [2]:

I.2.1 Enhancing Crop Productivity

Optimized water delivery ensures that crops receive the precise amount of water necessary for maximum growth and yield. Studies have shown that even marginal improvements in water application can lead to significant increases in crop output, which is especially crucial in regions where water scarcity limits agricultural expansion [3].

I.2.2 Economic and Environmental Sustainability

Reducing water waste through precision irrigation not only lowers production costs by minimizing unnecessary water and energy use but also preserves a critical natural resource. Efficient irrigation contributes to long-term sustainability by preventing soil degradation such as salinization and erosion and by reducing the runoff of fertilizers and pesticides, which can otherwise harm nearby water bodies [4].

I.2.3 Adaptation to Climate Change

In many parts of the world, changing precipitation patterns and rising temperatures have rendered traditional irrigation methods increasingly unreliable. Modern, automated irrigation systems can adapt to these variations by using real-time data to adjust water application schedules, thereby ensuring consistent crop performance even under fluctuating environmental conditions [5].

I.3 Overview of Irrigation Techniques

Irrigation methods can be broadly categorized into traditional (or conventional) techniques and modern precision approaches. Below, we detail several common methods along with their technical characteristics, advantages, and limitations [6].

I.3.1 Surface Irrigation

Surface irrigation systems distribute water by gravity over the soil surface. They remain widely used due to their low installation costs, despite notable inefficiencies [6].

I.3.1.1 Basin Irrigation

In basin irrigation, water is delivered to defined, level basins constructed around crop areas. This method is particularly effective in rice cultivation, where prolonged submersion benefits the crop [6].

- Advantages: Low capital expenditure; simple technology.
- Disadvantages: High evaporation losses; uneven water distribution; potential for waterlogging.

Figure.I.1: Surface Basin Irrigation

I.3.1.2 Furrow (Raei) Irrigation

Furrow irrigation involves directing water through channels dug between crop rows. Water infiltrates laterally from the furrow into the root zone [6].

- Advantages: Minimal energy requirements; relatively simple to implement.
- Disadvantages: Requires precise field leveling; efficiency is often low due to infiltration and runoff losses.

Figure.I.2: Furrow (Raei) Irrigation

I.3.1.3 Border (Planches) Irrigation

Border irrigation uses gently sloping fields bounded by ridges to guide water across the land [6].

- Advantages: Economical for flat or gently sloping fields.
- Disadvantage: Highly sensitive to field topography; prone to water loss through runoff.

Figure.I.3: Border (Planches) Irrigation

I.3.2 Sprinkler Irrigation

Sprinkler systems operate by pressurizing water and dispersing it through a network of pipes fitted with nozzles or sprinklers, simulating natural rainfall [7].

I.3.2.1 Fixed Sprinkler Systems

These systems feature permanently installed sprinklers that deliver water uniformly over a fixed area [7].

- Advantage: Can be designed to cover irregular fields; integrates well with fertigation.
- Disadvantages: High initial costs; vulnerable to wind drift and evaporation losses.

Figure.I.4: Fixed Sprinkler Systems

I.3.2.2 Mobile Sprinkler Systems (Pivots)

Mobile systems, such as center pivots, rotate about a central point to irrigate large fields. They are particularly suited to extensive agricultural operations in arid regions [8].

- Advantages: High coverage area; automation reduces labor.
- Disadvantages: High energy and maintenance costs; installation is capital intensive.

Figure.I.5: Mobile Sprinkler Systems (Pivots)

I.3.3 Drip (Goutte-à-goutte) Irrigation

Drip irrigation is a precision technique that irrigates water directly to the plant’s root zone via a network of tubes and emitters [9].

I.3.3.1 Surface Drip

Surface drip systems lay tubing on the soil surface to deliver water slowly and steadily, minimizing evaporation [9].

- Advantages: High water use efficiency; relatively simple maintenance.
- Disadvantages: Susceptible to clogging; requires filtration systems.

Figure.I.6 : Surface Drip (Goutte-à-goutte) Irrigation

I.3.3.2 Subsurface Drip

Subsurface drip involves burying the tubing beneath the soil surface, further reducing evaporation and ensuring consistent moisture at the root level [9].

- Advantages: Better water retention; raise weed growth; minimal evaporation.
- Disadvantages: More complex installation; difficult to inspect and repair once buried.

Figure.I.7 : Subsurface Drip (Goutte-à-goutte) Irrigation

I.3.4 Precision Irrigation with IoT

Precision irrigation represents the cutting edge of water management. By combining sensor networks, wireless communications, and automated control algorithms, these systems provide dynamic, real-time regulation of water delivery [10].

I.3.4.1 Sensor Integration and Data Analytics

Soil moisture, temperature, and even nutrient levels are monitored continuously using low-cost sensors. Data are transmitted via WIFI (e.g., ESP8266/ESP32 modules) or Xbee networks to a central controller (Arduino-based or similar), where algorithms decide on the optimal water application [10].

- Advantages: Maximizes crop yield while reducing water waste; enables predictive maintenance and remote monitoring.

- Disadvantages: Higher initial capital costs; requires technical expertise for calibration and maintenance.

I.3.4.2 Cloud and Mobile Integration

Using platforms such as Blynk, RemoteXY, or custom cloud solutions, farmers can remotely monitor system performance, adjust irrigation schedules, and receive real-time alerts [11].

- Advantages: Enhances operational flexibility; allows data-driven decision making.
- Disadvantages: Reliance on reliable network connectivity; cybersecurity concerns must be managed.

I.4 The Global Water Crisis and Its Impact on Irrigation

Despite the Earth's surface being over 70% water, only a minuscule fraction is accessible as fresh, potable water. The global water crisis is exacerbated by several factors [12]:

I.4.1 Scarcity and Uneven Distribution

Only about 1% of the Earth's water is readily available for human use. Water resources are unevenly distributed, with arid and semi-arid regions where agricultural demand is highest facing chronic shortages. This imbalance forces farmers to adopt inefficient irrigation practices, often leading to significant water losses [12].

I.4.2 Population Growth and Increasing Demand

Rapid population growth has increased the demand for food, thereby intensifying water use in agriculture. In many regions, traditional irrigation practices can no longer meet the rising needs without exacerbating water depletion [13].

I.4.3 Climate Change

Climate change introduces uncertainties in precipitation patterns and increases the frequency of droughts and extreme weather events. This variability not only disrupts traditional irrigation schedules but also necessitates adaptive, resilient water management systems [14].

I.4.4 Environmental Impacts

Inefficient irrigation methods contribute to problems such as soil salinization, waterlogging, and the contamination of water resources through runoff of fertilizers and pesticides. These environmental impacts further reduce the long-term viability of agricultural lands [15].

I.5 Challenges and Opportunities for Smart Irrigation

The challenges posed by inefficient water management are immense, but they also offer opportunities for transformative innovation through IoT and precision irrigation [16]:

I.5.1 Technical Challenges

Sensor Accuracy and Calibration: The reliability of soil moisture and weather sensors is critical. Variability in sensor performance due to environmental factors can affect decision accuracy [17].

System Integration: Combining multiple hardware components (microcontrollers, wireless modules, power supplies) into a cohesive system requires robust design and careful calibration [18].

Data Management and Security: The collection, processing, and storage of large datasets demand scalable cloud solutions and secure communication protocols [19].

I.5.2 Opportunities for Innovation

Real-Time Adaptive Control: IoT-based systems allow for real-time adjustments to irrigation schedules based on current soil and weather conditions, which can dramatically improve water use efficiency [20].

Remote Monitoring and Predictive Maintenance: Through mobile and cloud interfaces, farmers can monitor system performance from anywhere, receive alerts for potential failures, and perform maintenance proactively [21].

Integration with Agricultural Practices: Combining irrigation data with crop-specific growth models can optimize not only water use but also fertilizer application and overall farm management [22].

I.6 Conclusion

This chapter has provided an extensive overview of irrigation practices and the global water crisis, highlighting the critical need for efficient water management in agriculture. Traditional irrigation techniques while historically significant are increasingly unsustainable due to inefficiencies and environmental impacts. In contrast, IoT-based precision irrigation systems offer a promising solution by leveraging real-time data, automation, and advanced control algorithms. By addressing both the technical challenges and the broader environmental implications, these smart systems can pave the way for sustainable agricultural practices that conserve water, improve crop yields, and support global food security.

CHAPTER II

IoT Based Smart Irrigation Monitoring System using Cisco Packet Tracer

II.1 Introduction

This chapter presents a comprehensive design and implementation of the proposed IoT-based Greenhouse Monitoring System using Cisco Packet Tracer. The system aims to maintain optimal plant growth conditions by integrating sensors, actuators, and networking devices, thus facilitating both local and remote monitoring and control via smartphone and laptop through the internet. Key environmental parameters such as temperature, humidity, soil moisture, and CO_2 levels are monitored in real time, while automated triggers activate sprinklers, fans, and lighting systems as needed.

Cisco Packet Tracer is a network simulation tool that lets us design, configure, and test networks virtually, without needing real devices. It's based on a discrete-event simulation model, which means it simulates how data and events flow step by step through the network helping us see how devices behave in different scenarios.

The references used in this chapter from GITHUB and Cisco CCNA Certificate [23].

II.2 Over View of the Network Topology

The network topology of an IoT-based smart irrigation system defines how devices such as sensors, actuators, routers, servers, and user interfaces are interconnected. This section explains how data flows between these components to enable automation, remote monitoring, and real-time decision-making.

A well-structured topology ensures efficient communication, minimal delays, and seamless integration of IoT devices, making smart irrigation more effective and sustainable.

I used static routing in this network. That means I manually set up the routes for data to follow. Since the network design is small and doesn't change, static routing was simpler, more controlled, and avoided the extra complexity of dynamic routing protocols.

The IoT devices connect wirelessly to the Home Gateway, just like smartphones connect to Wi-Fi at home. Each device uses its built-in Wi-Fi card to join the gateway's Wi-Fi network (SSID), enters the password, and automatically gets an IP address from the gateway's DHCP service so it can communicate on the network.

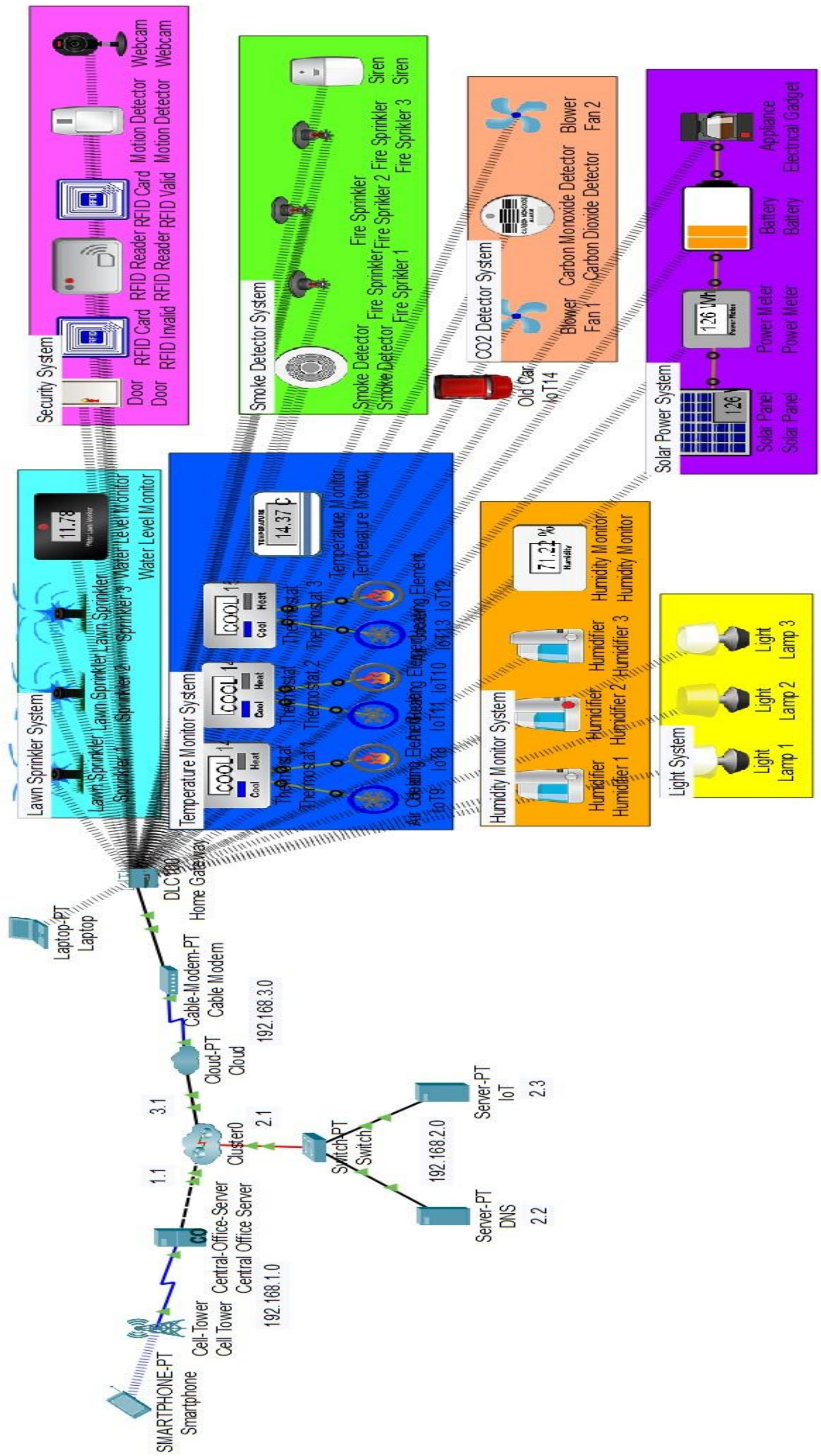

Figure.II.1: Network Topology

Figure.II.2: Physical Topology

II.2.1 System Requirements and Architecture

Every IoT-based smart irrigation system must meet functional and non-functional requirements for efficient operation. This section outlines the hardware, software, and network components, explaining their roles in real-time monitoring, automation, and remote access. A well-structured architecture ensures scalability, reliability, and security, making the system adaptable and efficient.

Functional Requirements

- **Real-time Sensing:** Continuous measurement of temperature, humidity, soil moisture, and CO_2 levels.
- **Automated Control:** Actuation of devices (sprinklers, fans, lights) based on sensor thresholds.
- **Remote Access:** Monitoring and control capabilities via smartphones, tablets, or computers.
- **Alert Mechanisms:** Notification protocols (e.g., email or push notifications) for abnormal conditions, such as high temperatures or smoke detection.

Non-Functional Requirements

- **Reliability:** Consistent system uptime and data availability.

- **Security:** Safe data transmission and restricted access to control systems.
- **Scalability:** Ability to integrate additional sensors and actuators or extend to multiple greenhouses.

System Architecture

- **Sensors Layer:** Devices that gather environmental data (temperature, humidity, CO_2, smoke, etc.).
- **Network Layer:** Routers, switches, and access points that interconnect sensors, servers, and user devices.
- **Application Layer:** An IoT server or cloud platform that processes data, executes automation logic, and provides a user interface.

II.2.2 Hardware Components

The hardware components of an IoT-based smart irrigation system include sensors, actuators, networking devices, and computing units, all working together to monitor environmental conditions, process data, and automate irrigation tasks. These elements ensure efficient water management, real-time monitoring, and remote control, enhancing the system's accuracy, reliability, and scalability.

Sensors

Sensors are responsible for collecting real-time environmental data to determine when irrigation is needed. The key sensors used in this system include:

- **Temperature Sensor** → Measures ambient temperature to regulate greenhouse conditions.
- **Humidity Sensor** → Monitors moisture levels in the air to control ventilation.
- **Soil Moisture Sensor** → Detects soil dryness and triggers irrigation when necessary.
- **CO_2 Sensor** → Ensures proper carbon dioxide levels for plant growth.
- **Smoke/Fire Sensor** → Detects smoke or fire hazards and activates safety protocols.

Actuators

Actuators perform automated actions based on sensor readings. These include:

- **Sprinkler System** → Activates irrigation based on soil moisture levels.
- **Ventilation Fan** → Controls airflow to regulate temperature and humidity.
- **LED Grow Lights** → Supplements natural light for plant growth.

- **Heater/Air Conditioner** → Maintains optimal temperature if needed.

Networking Devices

Networking components enable communication between devices in the system:

- **Router ISP (Internet Service Provider):** Manages internet connectivity and IP addressing for the devices.
- **Switch:** Facilitates data exchange between core network devices such as servers.
- **Home Gateway (Wireless Access Point):** A wireless access point that connects IoT devices to the network.
- **Cable Modem-PT:** Connects the Home Gateway to the ISP via the cloud, provides a link to the internet enabling remote access.
- **Cloud-PT:** Represents internet access for remote monitoring.

Computing Units

These devices process sensor data and manage system operations:

- **IoT Sensors & Actuators:** Devices like temperature sensors, humidity sensors, and water pumps that collect data and execute irrigation actions.
- **IoT Server:** Manages device registration, stores sensor data, and executes automation rules.
- **DNS Server:** Translates human-readable domain names into IP addresses for remote access.
- **Central Office Server:** Manages backbone services for the ISP, enabling remote access.
- **Cell Tower:** Ensures mobile cellular connectivity, allowing users to access the system from smartphones.
- **User Devices (Smartphone, Laptop, Desktop):** Allow users to monitor and control the system remotely.

This network topology enables efficient data transmission, remote system control, and automation of the irrigation process, ensuring optimized water usage and improved crop health.

II.3 Network Topology and Addressing

Network topology defines how devices in an IoT-based smart irrigation system are connected, both physically and logically, to enable efficient data exchange and automation. Addressing ensures that each device has a unique IP, allowing for seamless communication, structured data flow, and remote accessibility. By integrating wired and wireless connections, the system facilitates real-time monitoring and automated irrigation control, ensuring optimal performance and efficient resource management.

Static and dynamic IP addresses:

- Static IP Addresses → Assigned to core networking devices (Router, IoT Server, DNS Server) to ensure consistent communication.
- Dynamic IP Addresses (DHCP) → Used for client devices like smartphones and laptops, allowing automatic network configuration.
- Layer 2 Device (Switch) → Does not require an IP address as it operates at the MAC level, facilitating wired connections.
- Cloud-PT & Cable Modem receive dynamic addresses from the ISP to connect the local network to the internet.

Device	**Connected To**	**IP Address / DHCP**
Home Gateway	Laptop, IoT Devices, Cable Modem	192.168.3.1 (Static)
Cable Modem	Cloud-PT	Dynamic from ISP
Cloud-PT	Router-PT (ISP)	Dynamic
Router-PT (ISP)	Switch-PT, Central Office Server	192.168.2.1 (Static)
Switch-PT	Router, DNS Server, IoT Server	Layer 2 Device
DNS Server	Switch-PT	192.168.2.2 (Static)
IoT Server	Switch-PT	192.168.2.3 (Static)
Central Office Server	Router-PT, Cell Tower	192.168.1.0 (Network)
Cell Tower	Central Office Server	Dynamic
Smartphone	Home Gateway (WIFI)	DHCP
Laptop	Home Gateway (WIFI)	DHCP

Table.II.1: Network Topology Addresses

Starting with opening new page file in packet tracer, then dropping all devices needed in this network from **Device Palette**. It’s usually located at the bottom-left side of the screen.

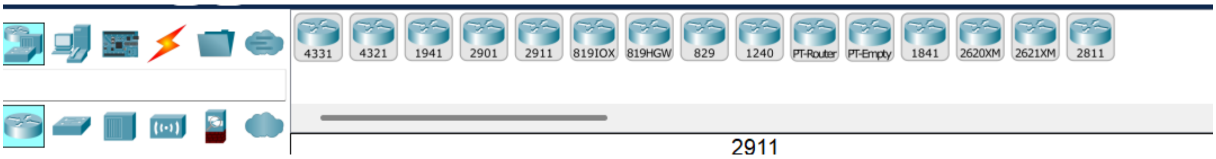

Figure.II.3 : Device Palette (Tools)

II.3.1 physical connection and cable types:

A network's physical connection determines how devices are wired together to ensure stable and efficient communication. In an IoT-based smart irrigation system, selecting the right cable types is crucial for reliable data transmission between components like routers, switches, servers, and IoT devices. By integrating both wired and wireless connections, the system enables high-speed data transfer, automation, and remote monitoring for optimal performance.

1. Connections in the Core Network:

- Smartphone-PT ↔ Cell Tower → Wireless Connection
- Cell Tower ↔ Central Office Server → Coaxial Cable
- Central Office Server (Fa0/0) ↔ Router-PT (ISP) (Fa0/0) → Copper Cross-Over Cable

2. ISP and Backbone Network Connections:

- Router-PT (ISP) (Fa1/0) ↔ Cloud-PT (Eth6) → Copper Straight-through Cable
- Cloud-PT (Coax7) ↔ Cable Modem-PT (Coaxial Connection) → Coaxial Cable
- Cable Modem-PT ↔ Home Gateway (DLC100) → Copper Straight-through Cable

3. Local Network and IoT Devices:

- Home Gateway ↔ Laptop-PT → Wireless Connection (Wi-Fi)
- Home Gateway ↔ IoT Devices → Wireless Connection (Wi-Fi)
- Router-PT (ISP) (Fa4/0) ↔ Switch-PT (Fa4/1) → Copper Straight-through Cable (red line due to Packet Tracer display issue)
- Switch-PT (Fa0/1) ↔ DNS Server-PT (Fa0/0) → Copper Straight-through Cable
- Switch-PT (Fa1/1) ↔ IoT Server-PT (Fa0) → Copper Straight-through Cable

4.Cable Types and Their Roles:

- Coaxial Cable → Used for broadband connections (e.g., linking Cloud-PT to the cable modem).
- Copper Straight-Through Cable → Connects different network devices, such as a router to a switch or a switch to a server.

- Copper Crossover Cable → Connects similar devices, such as a router to a router or a switch to a switch.
- Wireless (Wi-Fi) → Used for IoT devices, laptops, and smartphones, ensuring mobility and ease of access.

The combination of these physical connections and cable types ensures fast, reliable, and scalable communication, allowing for efficient remote monitoring and automation of the irrigation system.

Final Network Summary:

- The Home Gateway connects to the ISP via Cable Modem.
- The Home Gateway provides internet to the Laptop over Wi-Fi.
- All IoT devices are connected to the Home Gateway wirelessly.
- The Laptop and Smartphone can control the IoT devices remotely if remote access is configured correctly.

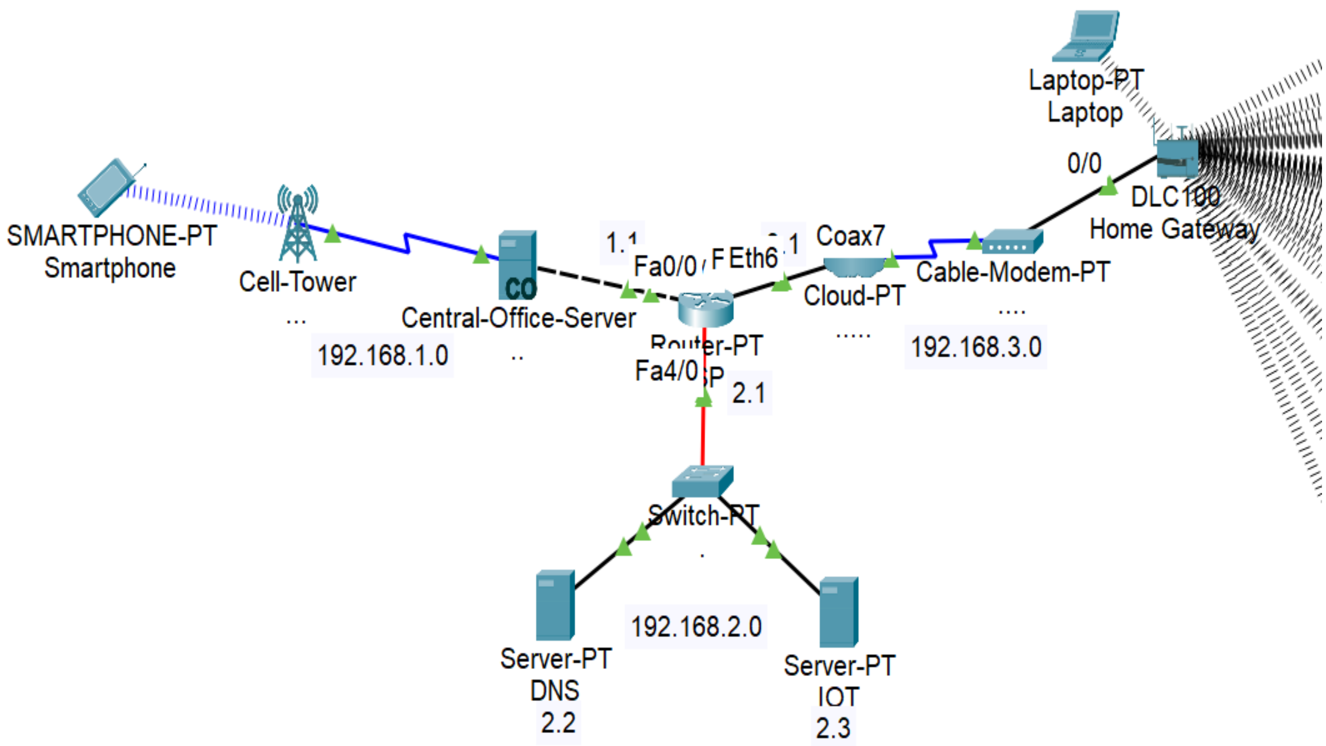

Figure.II.4: ISP Network

II.3.2 Addressing in ISP (router):

The ISP router is a critical component in an IoT-based smart irrigation system, responsible for managing network communication, internet access, and device connectivity. It assigns IP addresses to various devices, ensuring efficient data flow, structured device identification, and seamless communication within the network. By using a combination of static and dynamic IP assignment methods, the router enables remote access, automation, and optimized traffic management. This structured addressing system allows the local network to connect to the internet efficiently, ensuring real-time monitoring and control of irrigation processes.

After entering CLI then entering configuration mode

- enable
- configure terminal

Assign IP Addresses to Interfaces

Fa0/0 (Connected to Central Office Server)

- interface FastEthernet0/0
- ip address 192.168.1.1 255.255.255.0
- no shutdown
- exit

Fa1/0 (Connected to Cloud-PT)

- interface FastEthernet1/0
- ip address 192.168.3.1 255.255.255.0
- no shutdown
- exit

Fa4/0 (Connected to Switch-PT for DNS & IoT Servers)

- interface FastEthernet4/0
- ip address 192.168.2.1 255.255.255.0
- no shutdown
- exit

This can also be done without entering commands in CLI and just enter Config then turning Port Status ON for the chosen interface and filling in IP Configuration

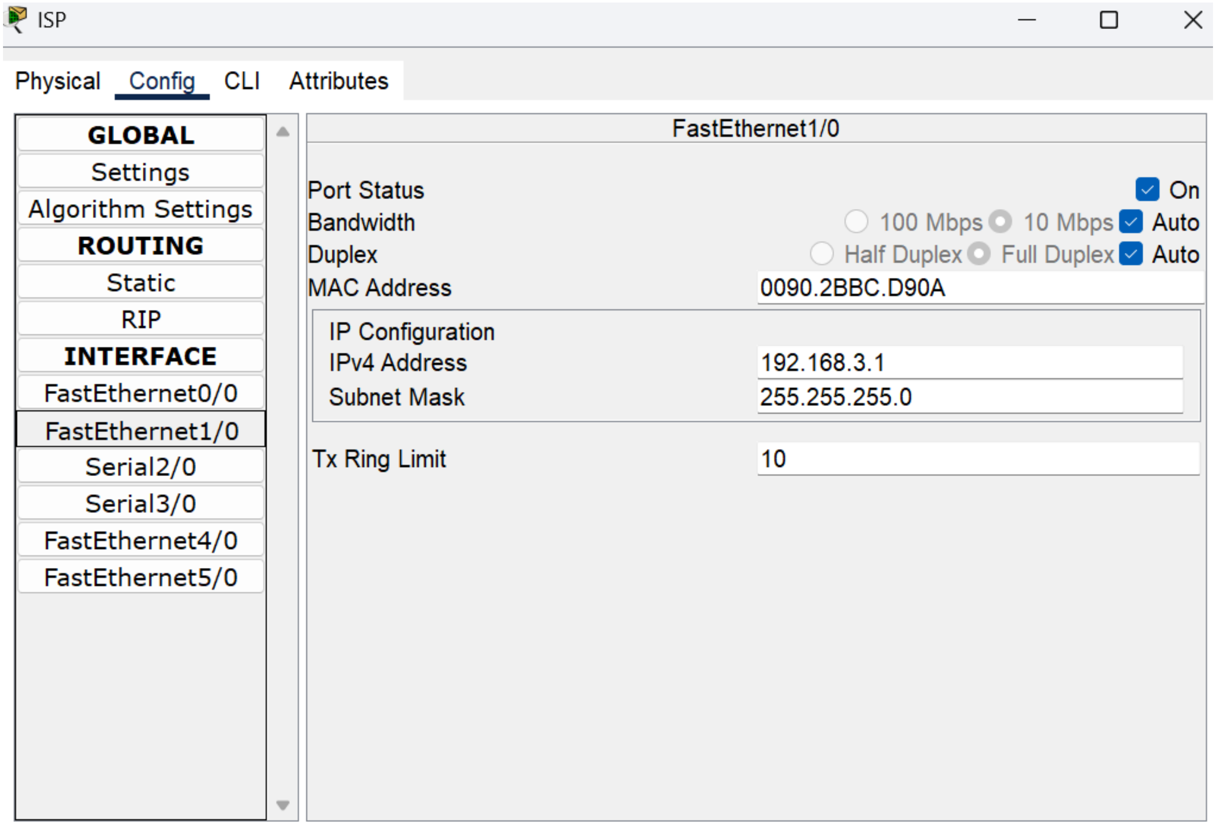

Figure.II.5: ISP Config Addressing

II.3.3 DHCP Configuration:

DHCP (Dynamic Host Configuration Protocol) automatically assigns IP addresses, default gateways, and DNS settings to network devices, reducing manual configuration and ensuring efficient IP management.

II.3.3.1 DHCP Exclusion for Reserved Addresses:

Before assigning dynamic IPs, certain addresses are reserved for critical devices such as routers and servers. These excluded IPs prevent conflicts.

Configuration:

- ip dhcp excluded-address 192.168.1.1 192.168.1.5
- ip dhcp excluded-address 192.168.3.1 192.168.3.5
  - 192.168.1.1 - 192.168.1.5 → Reserved for Cell Tower, Central Office Server
  - 192.168.3.1 - 192.168.3.5 → Reserved for Home Gateway and Core Networking Devices

II.3.3.2 DHCP Configuration for Mobile Network (Cell Tower):

The Cell Tower serves as a communication bridge for remote access and mobile devices such as smartphones. The router assigns IP addresses dynamically to mobile devices.

Configuration:

- ip dhcp pool CellTower
- network 192.168.1.0 255.255.255.0
- default-router 192.168.1.1
- dns-server 192.168.2.2
    - Network: 192.168.1.0/24 (for mobile connectivity)
    - Default Gateway : 192.168.1.1 (Cell Tower or Gateway device)
    - DNS Server : 192.168.2.2 (Configured for domain name resolution)

NOTES:

* The "/24" in 192.168.1.0/24 is a CIDR (Classless Inter-Domain Routing) notation that represents the subnet mask.

What does /24 mean?

- /24 means that the first 24 bits of the IP address are reserved for the network portion, leaving the remaining 8 bits for host addresses (8x32=256).
- It is equivalent to the subnet mask 255.255.255.0.
- This allows 254 usable IP addresses in the range 192.168.1.1 to 192.168.1.254 (since .0 is the network address and .255 is the broadcast address).

If more devices were needed, a larger subnet (e.g., /23 or /22) could be used to allow more IPs.

* The default gateway is the IP address of a router or gateway device that forwards network traffic from local devices to other networks, including the internet or different subnets.

- 192.168.1.1 (Cell Tower or Gateway device) acts as the default gateway for mobile devices, directing their traffic beyond the 192.168.1.0/24 subnet.
- It ensures that devices can communicate outside their local network, such as accessing the internet or another subnet like 192.168.2.0 (servers) or 192.168.3.0 (IoT/home gateway).

II.3.3.3 DHCP Configuration for Home Gateway IoT Devices & Local Network:

The Home Gateway (HG) is responsible for managing IoT device connections, ensuring each sensor, actuator, and controller receives an appropriate IP address.

Configuration:

- ip dhcp pool HG
- network 192.168.3.0 255.255.255.0
- default-router 192.168.3.1
- dns-server 192.168.2.2
  - Network: 192.168.3.0/24 (for IoT devices and user systems)
  - Default Gateway: 192.168.3.1 (Home Gateway)
  - DNS Server: 192.168.2.2 (To resolve IoT services and cloud connectivity)
- end
- write memory (WR) (Saves DHCP configuration)

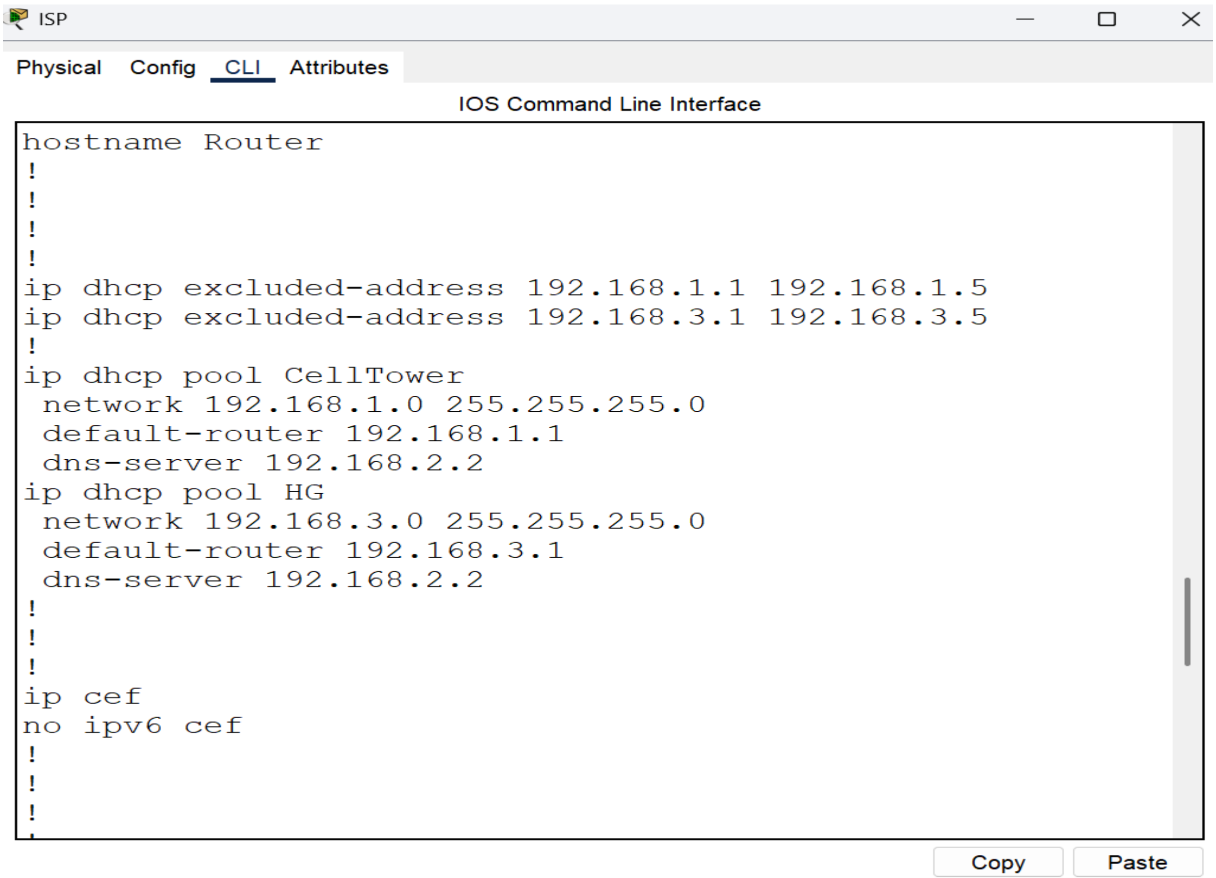

Figure.II.6: ISP CLI Configuration

II.3.4 Assign IPs for DNS & IoT Servers:

Assigning IP addresses for DNS and IoT servers is a crucial step in an IoT-based smart irrigation system, ensuring stable communication and accessibility within the network. The DNS server translates domain names into IP addresses, making it easier to access IoT services, while the IoT server stores and manages sensor data, executing automation tasks. Proper IP assignment ensures that these servers function correctly, providing reliable network operations and remote access capabilities.

DNS Server → Desktop → IP Configuration→ Filling as shown below:

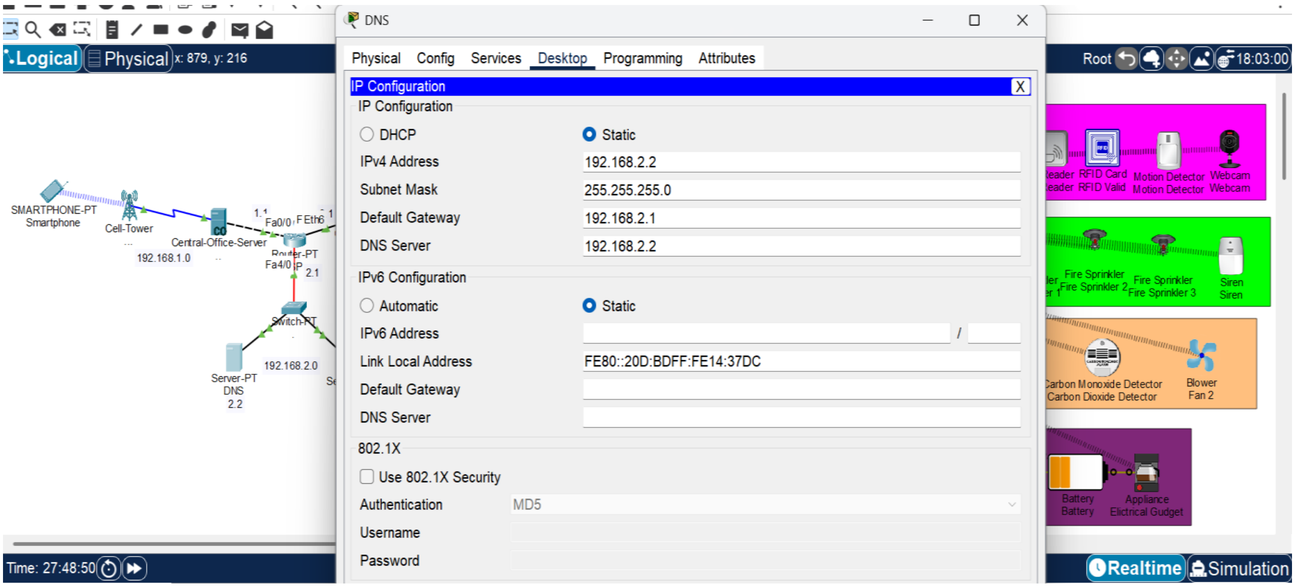

Figure.II.7: Assign Static IP for DNS Server

IoT Server → Desktop → IP Configuration→ Filling as shown below:

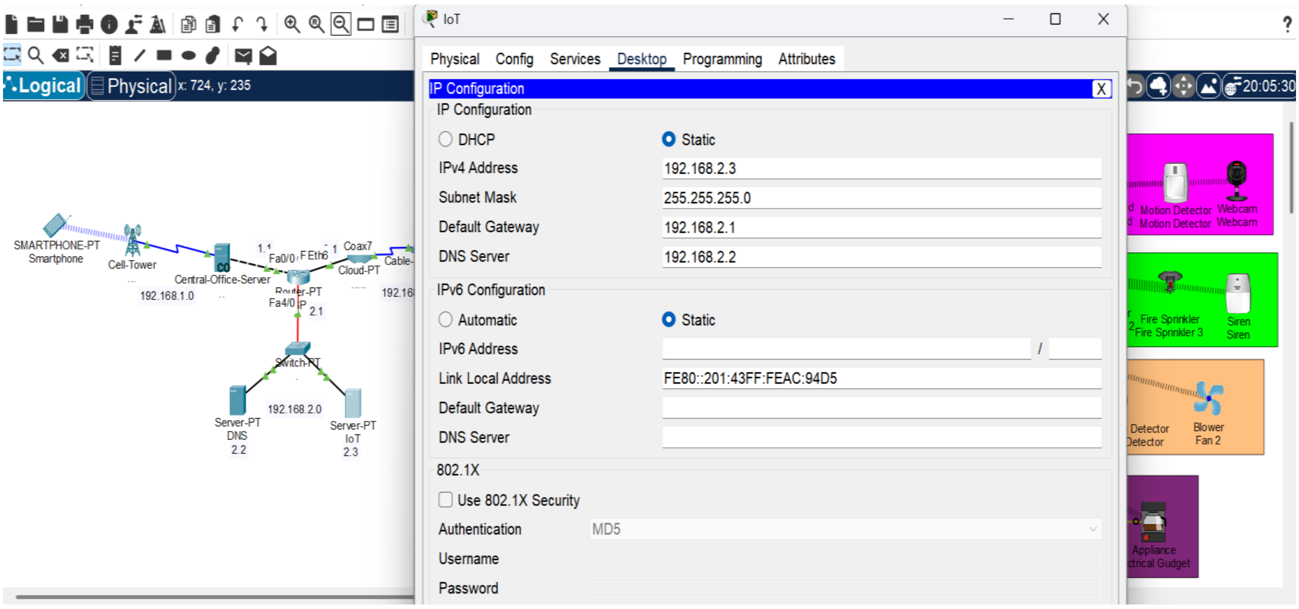

Figure.II.8: Assign Static IP for IoT Server

II.3.5 Enable DNS Service:

DNS server plays a critical role in simplifying device communication by mapping domain names to IP addresses. Without DNS, users would need to remember complex numerical IPs to access IoT services, making network management more difficult.

DNS Server → Services → DNS:

- DNS Service: **ON**
- Name: www.iot.org (inter preferred name)
- Adress: 192.168.2.3 (IoT Server IP Address)

the IoT Server now has a domain name mapped to its IP address (192.168.2.3) via the DNS server, allowing devices to access it using a human-friendly name instead of its IP.

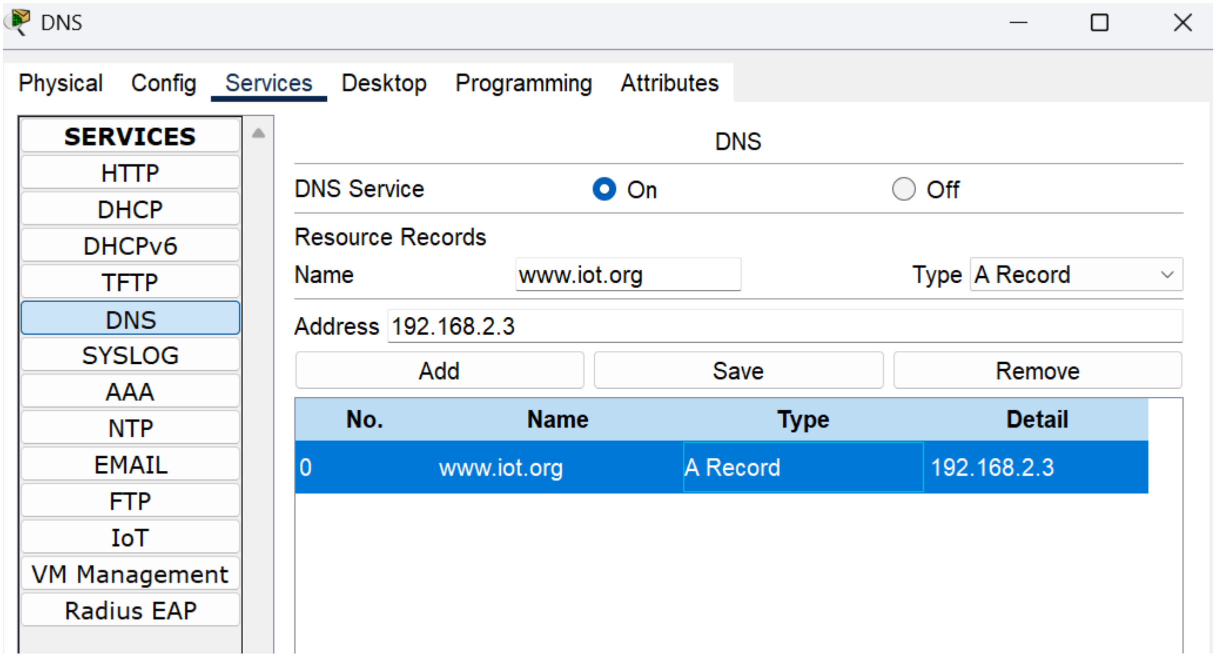

Figure.II.9: Enable DNS Service

II.3.6 Enable IoT Service:

In an IoT-based smart irrigation system, enabling the IoT service allows devices like soil moisture sensors, temperature sensors, and water pumps to communicate and function autonomously. Without an active IoT service, devices would be unable to transmit data or receive automation commands.

IoT Server → Services → IoT:

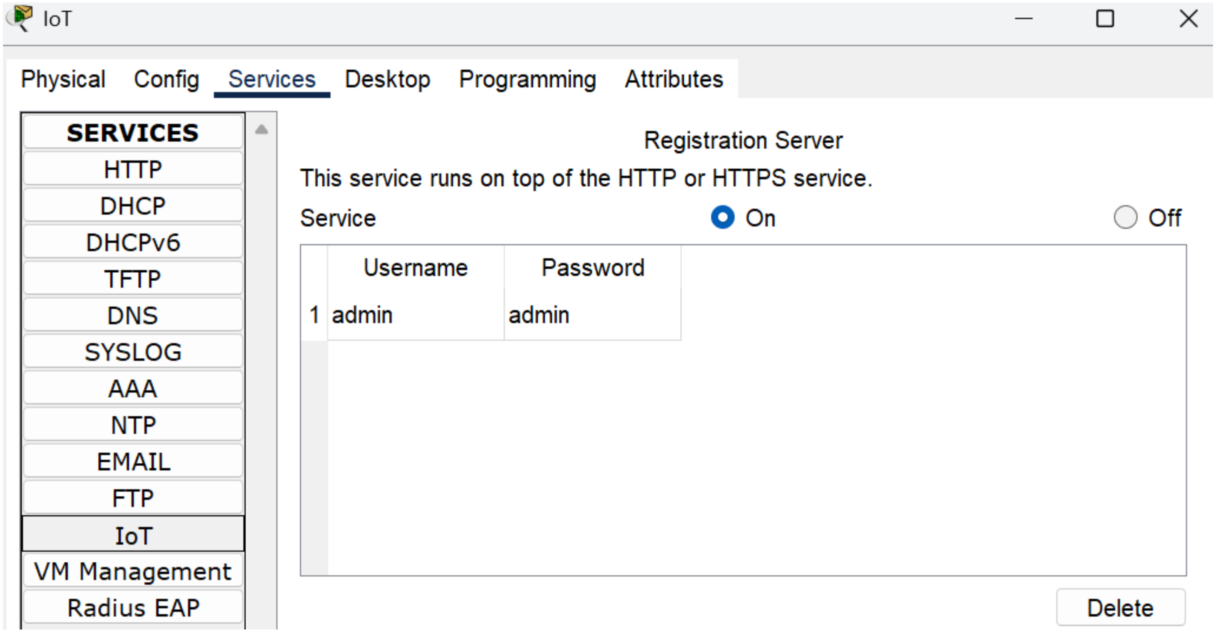

Figure.II.10: Enable IoT Service

II.3.7 DHCP Verification & Troubleshooting:

Testing network connectivity in an IoT-based smart irrigation system is essential to ensure smooth communication between routers, servers, and IoT devices. It helps detect connection failures, misconfigured IPs, or service unavailability, enabling timely troubleshooting. The process involves verifying IP assignments, checking DNS resolution, and ensuring IoT services are accessible, allowing network administrators to identify and resolve issues for seamless data exchange and remote access.

Central Office Server → Config → Backbone → IP Configuration → DHCP

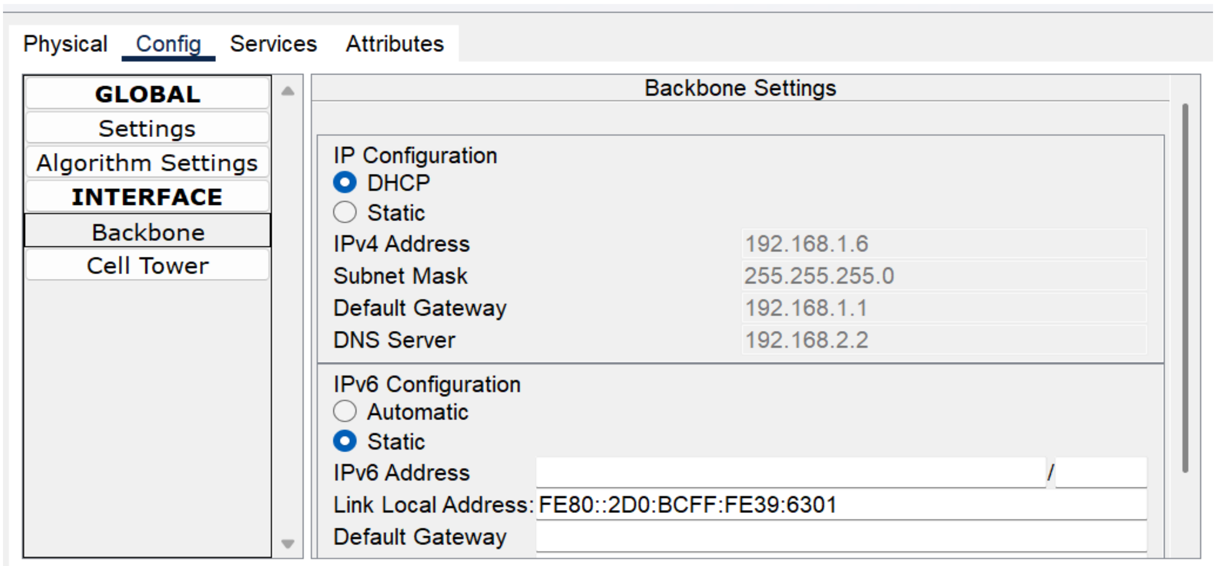

Figure.II.11: Central-Office Server DHCP Verification

Home Gateway → Config → Internet → IP Configuration → DHCP

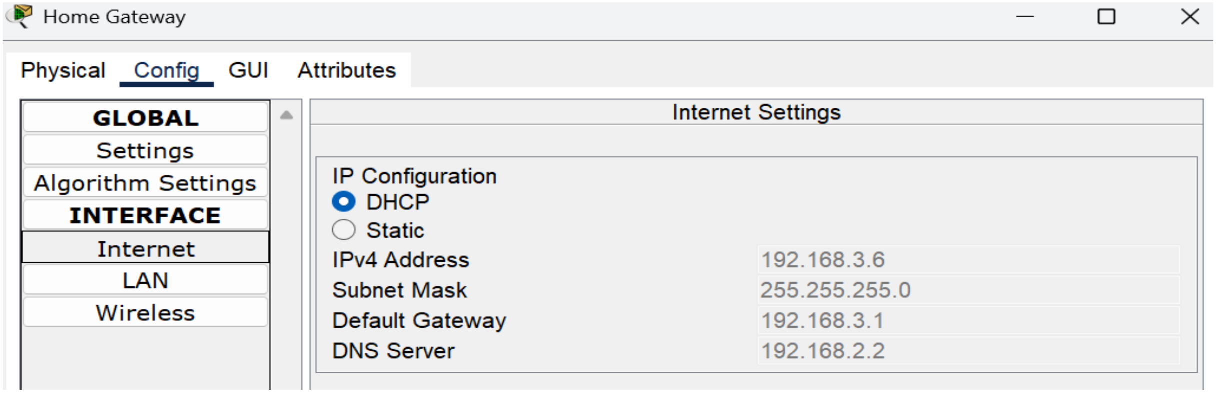

Figure.II.12: Home Gateway DHCP Verification

NOTE:

* For Home Gateway to receive an IP Address via ISP, Enable cable coaxial connection between cloud and cable modem:

1. Cloud-PT → Config → Ethernet6 → Provider Network → Interface → Cable
2. Cloud-PT → Config → Connections → Cable → Coaxial7 ←→ Ethernet6 → ADD

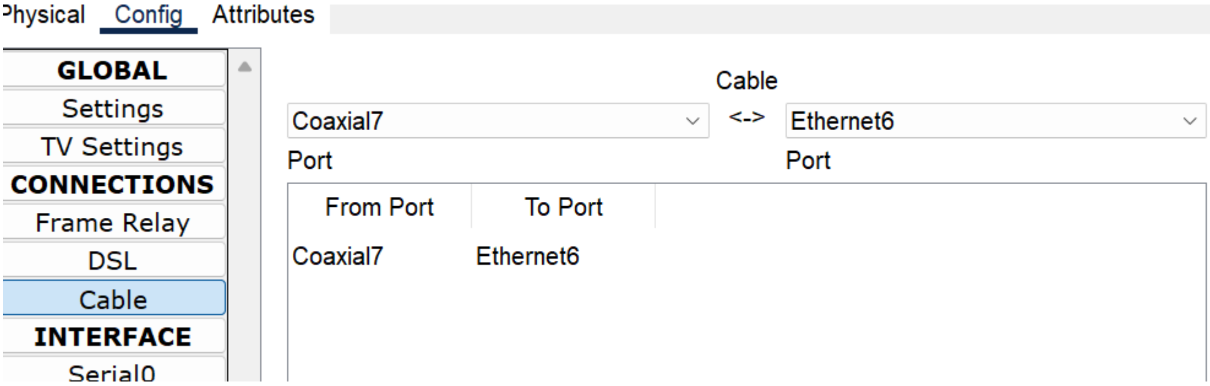

Figure.II.13 : Port (Coax7) to Port (Eth6) Cable Connection

II.4 IoT Devices Connection & Monitoring

IoT Devices Connection & Monitoring involves integrating sensors, actuators, and controllers into a smart irrigation system to enable real-time data collection and automation. Proper configuration allows the system to respond automatically to changes in temperature, soil moisture, and humidity, ensuring efficient irrigation and remote management. By establishing seamless communication with the IoT server, devices enable automated irrigation control and environmental monitoring, optimizing resource use and decision-making.

II.4.1 Connecting laptop and IoT Devices to the Home Gateway:

Home Gateway → Wireless → SSID (HomeGateway) → Authentication → WPA2- PSK (PSK Pass Phrase: IOT_2025) → Encryption Type (AES)

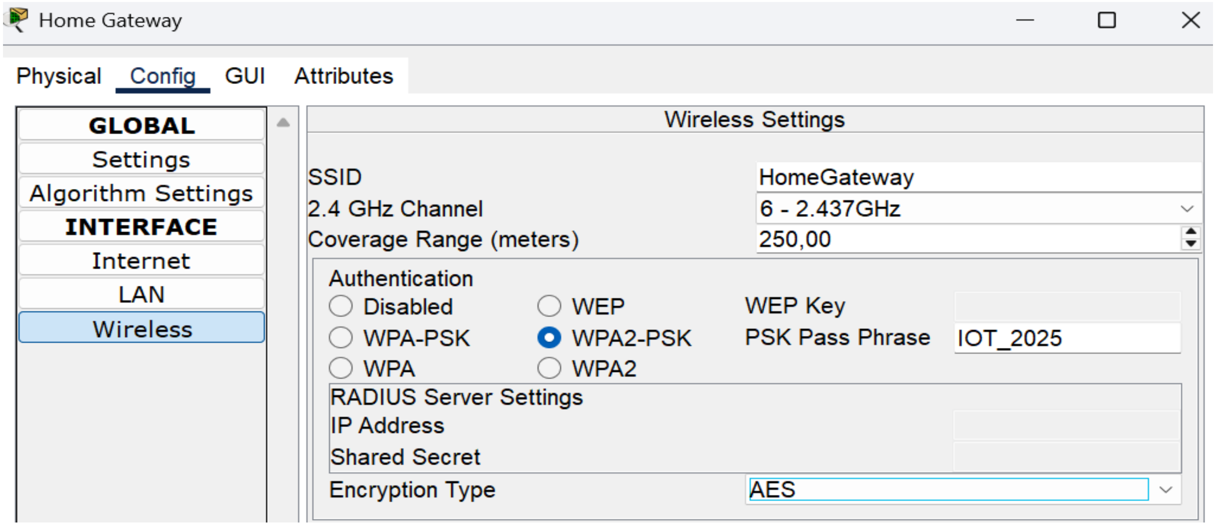

Figure.II.14: Home Gateway Wireless Implementation

Now, checking laptop's IP Addressing by changing from Static to DHCP:

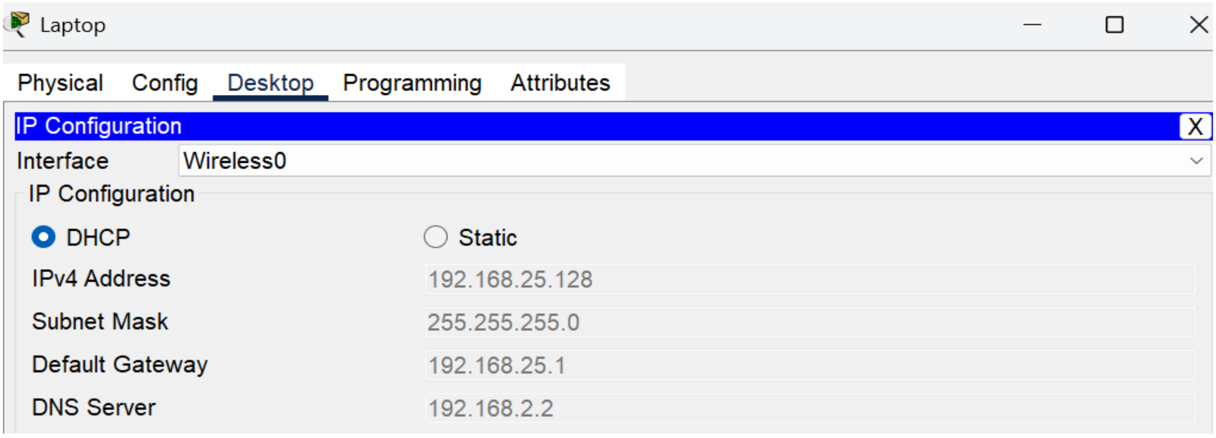

Figure.II.15: Laptop DHCP Verification

II.4.1.1 Connecting Laptop to Home Gateway:

Laptop → Config → Wireless0 → Turn ON → SSID (HomeGateway) → WPA2- PSK (PSK Pass Phrase: IOT_2025) → Encryption Type (AES)

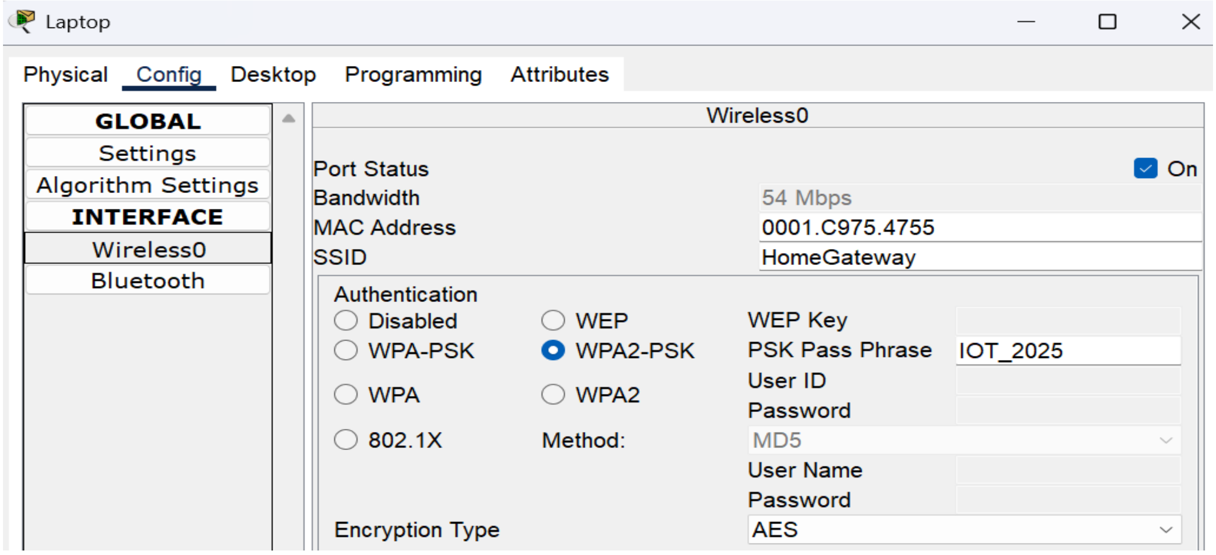

Figure.II.16: Laptop Wireless Connection

II.4.1.2 Connecting IoT Devices to Home Gateway:

will do just one example but it has to be done to all the IoT Devices

Sprinkler 2 → Config → Wireless0 → Turn ON → SSID (HomeGateway) → WPA2- PSK (PSK Pass Phrase: IOT_2025) → Encryption Type (AES)

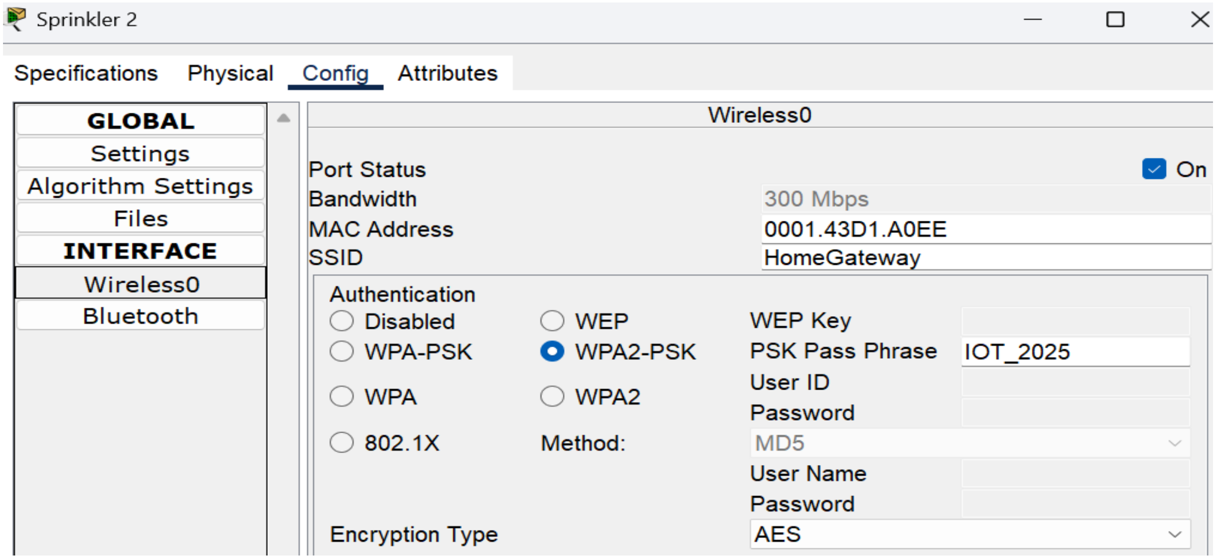

Figure.II.17: IoT Device Wireless Connection

II.4.1.3 IoT Devices Connection for Monitoring Through IoT Server:

Sprinkler 2 → Config → Settings → Gateway/DNS IPv4 → Static to DHCP →

IoT Server → Remote Server:

- Server Address → 192.168.2.3
- Username → admin
- Password → admin

Then Press **Connect**

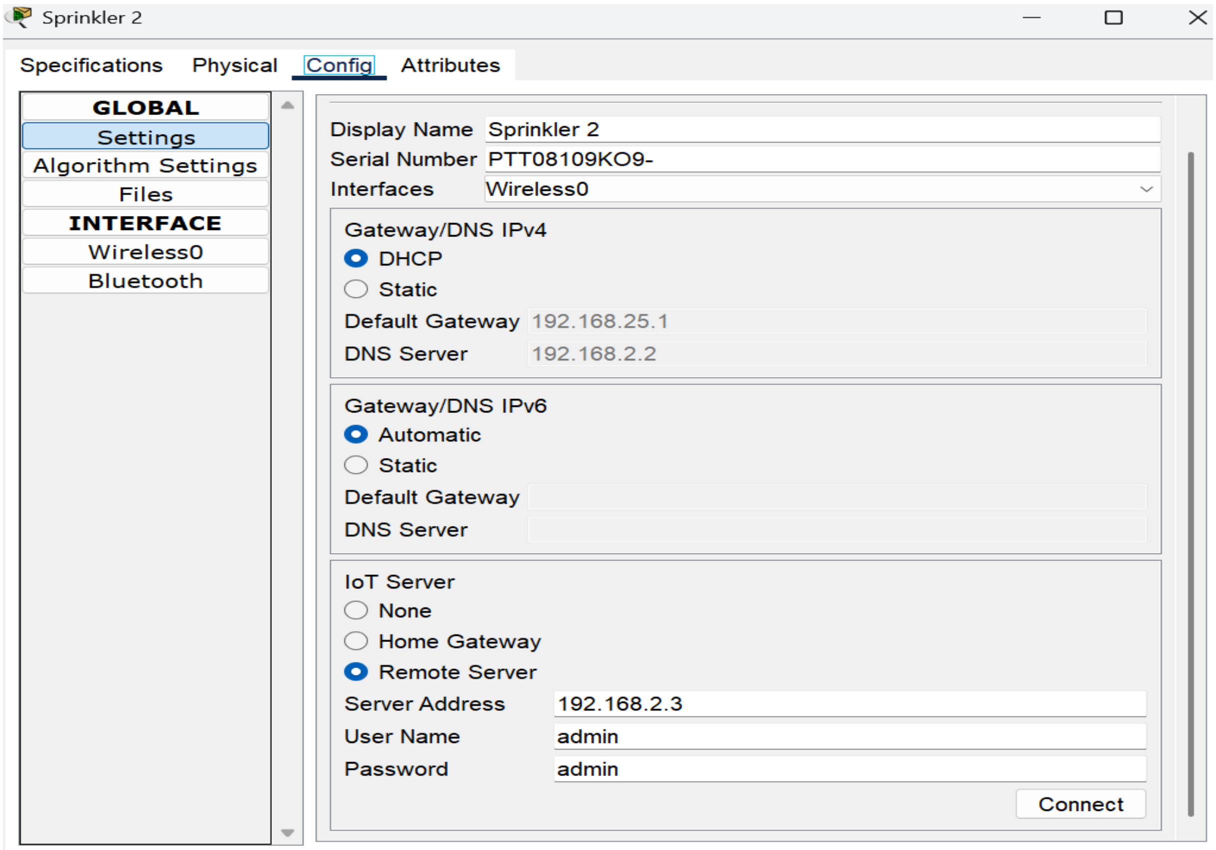

Figure.II.18: Setting IoT Device Remote Server

For some IoT devices you may not find Wireless Interface, in order to change it do the following steps:

Solar Panel → Advanced → I/O Config → Network Adapter → PT-IOT-NM-1W

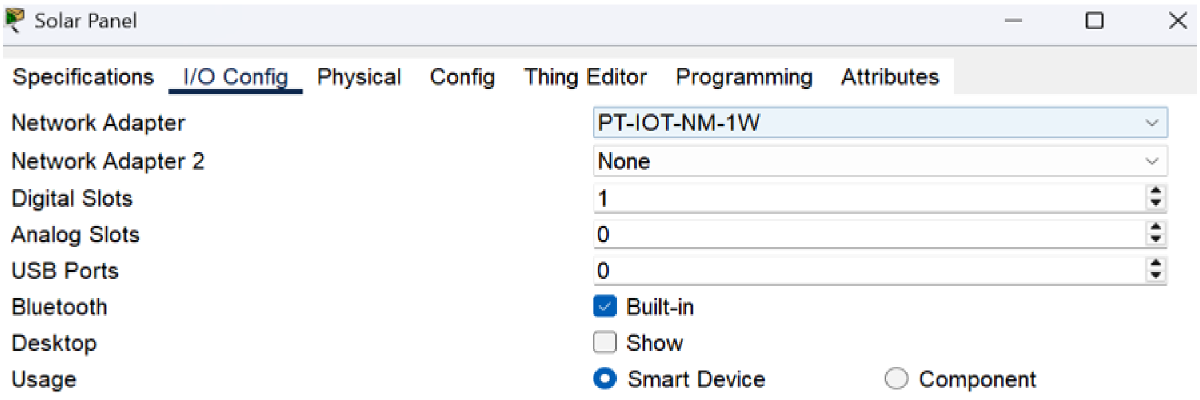

Figure.II.19: Setting IoT Device Remote Server

II.4.2 Monitoring IoT Devices:

II.4.2.1 Accessing the IoT Server:

Using the IP Address on either laptop or smartphone:

Laptop → Desktop → IoT Monitor → Fill in as shown below → Login

* Before Login, Sign up first

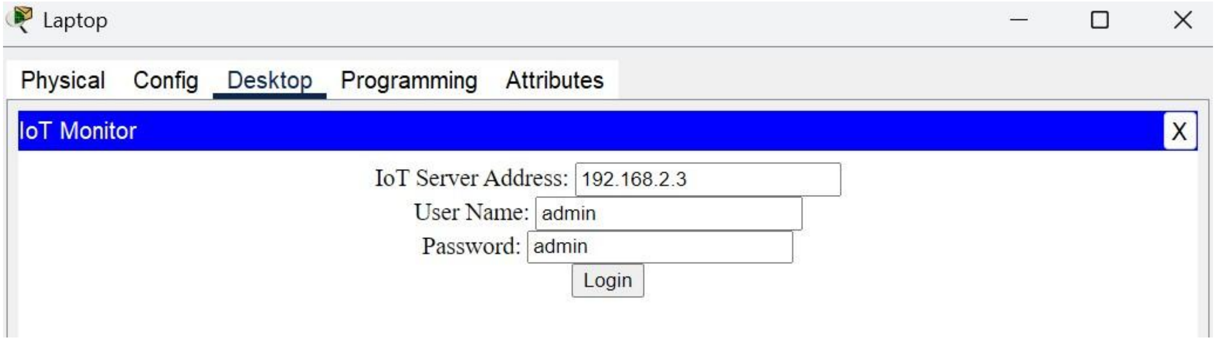

Figure.II.20: Sign up And Login Through Laptop using IP Address

Using the Domain name on either laptop or smartphone:

Smartphone → Desktop → IoT Monitor → Fill in as shown below → Login

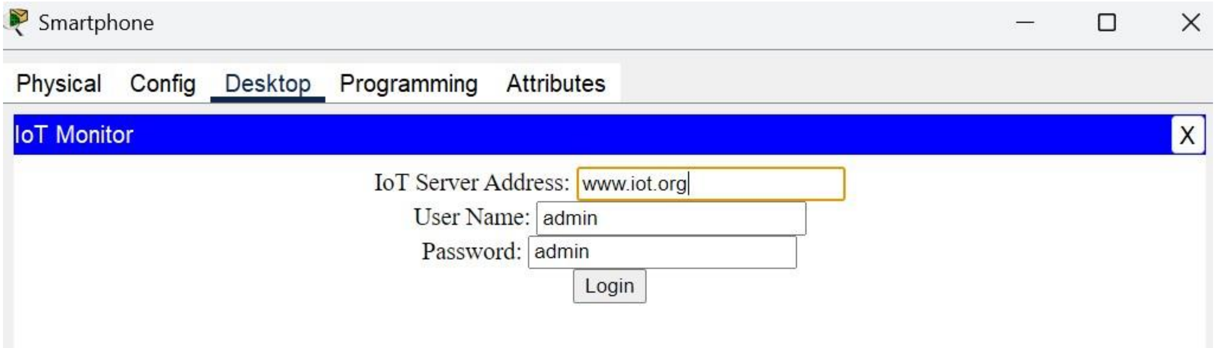

Figure.II.21: Login Through Smartphone using Domain Name

After Logging in IoT Monitor shows in Home all the IoT Devices connected

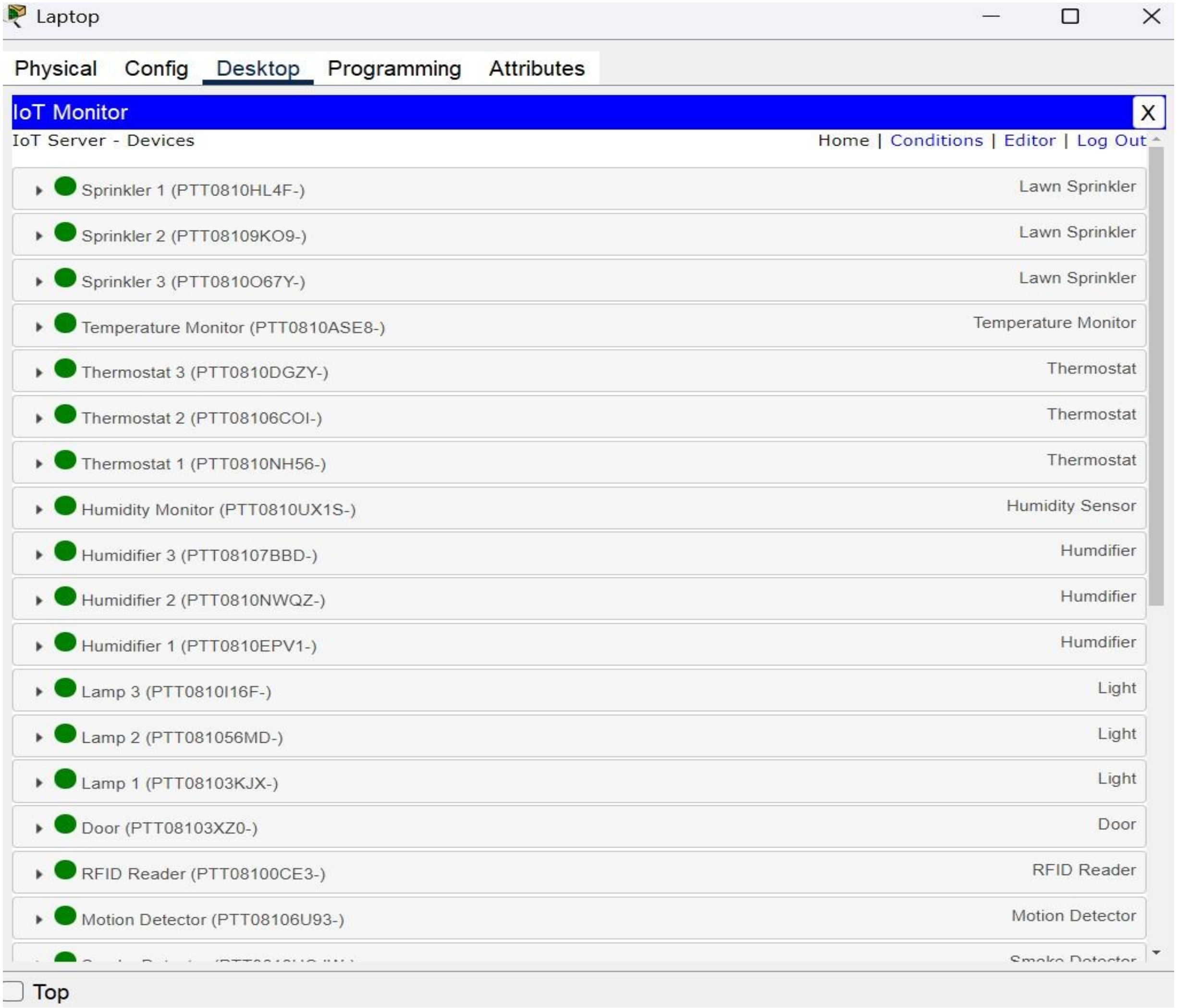

Figure.II.22: IoT Devices Connectivity

II.4.2.2 Creating Conditions & Actions:

The IoT Monitor allows define if-then rules for automation

Adding a New Condition

1. Click "Add" or "Edit" next to the Actions tab.
2. Select the sensor or device that want to monitor (e.g., Temperature Monitor).
3. Specify the condition (e.g., Temperature Monitor Temperature > 30.0).
4. Select the action (e.g., Set Fan 1 Status to ON).
5. Click Save or Apply.

Enabling/Disabling Conditions

- In the IoT Monitor list, can enable or disable rules with a checkbox.
- Enabled rules trigger automatically when their condition is met.
- Disabled rules are ignored.

II.4.2.3 Greenhouse Subsystem Monitoring:

Effective monitoring of IoT devices ensures that the smart irrigation system operates efficiently by detecting failures, misconfigurations, or network issues before they disrupt automation. By tracking sensor data, verifying connectivity, and troubleshooting issues proactively, the system ensures efficient, real-time automation and optimal irrigation performance.

❖ **Lawn Sprinkler System**

This system uses a water level or soil moisture sensor evaluates how much water is in the soil. When moisture levels drop below a predetermined value, the lawn sprinkler turns on, ensuring plants receive adequate irrigation without overwatering, automatically activating sprinklers whenever readings drop below a preset threshold (e.g., ≤ 12).

Figure.II.23: Lawn Sprinkler System

➢ **Role & Purpose:**

- Monitors soil moisture or water level and automatically irrigates plants when needed.
- Ensures consistent watering to prevent under- or over-watering.

➢ **Automation Example:**

- Condition: If Water Level is below a threshold (e.g., < =12cm)
- Action: Turn Sprinkler ON (Set Sprinkler Status to True).
- Condition: If Water Level recovers above the threshold
- Action: Turn Sprinkler OFF to conserve water.

IoT Monitor X

IoT Server - Device Conditions   Home | Conditions | Editor | Log Out

Actions	Enabled	Name	Condition	Actions
Edit Remove	Yes	Sprinkler ON	Water Level Monitor Water Level <= 12.0 cm	Set Sprinkler 1 Status to true Set Sprinkler 2 Status to true Set Sprinkler 3 Status to true
Edit Remove	Yes	Sprinkler OFF	Water Level Monitor Water Level >= 20.0 cm	Set Sprinkler 1 Status to false Set Sprinkler 2 Status to false Set Sprinkler 3 Status to false

Figure.II.24: Lawn Sprinkler Automation Conditions

❖ Temperature Monitoring System

This system includes temperature sensors, a thermostat, and heating/cooling elements. The temperature sensor tracks ambient conditions, and the thermostat activates a heater or cooler if readings move beyond a preset range. By automatically regulating temperature, it ensures plants remain in an optimal environment for healthy growth.

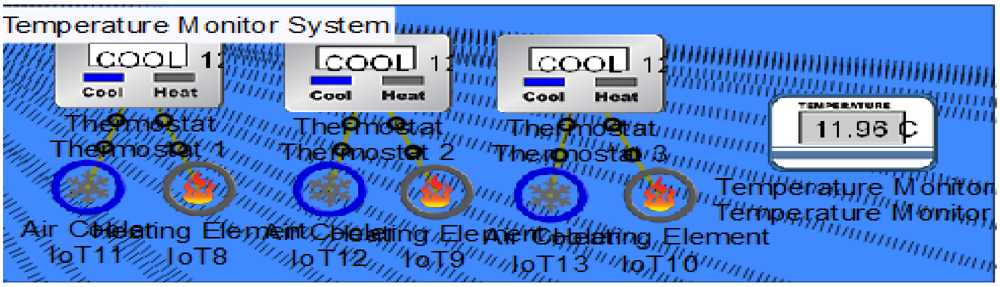

Figure.II.25: Temperature Monitor System

➢ **Role & Purpose:**

- Maintains an optimal temperature range for plant growth.
- Includes a temperature sensor, thermostat, heater, and cooler.

➢ **Automation Example:**

- Condition: If Temperature ≤ 0°C,
- Action: Turn Heater ON (Set Thermostat Status to Heating).
- Condition: If Temperature ≥ 20°C,
- Action: Turn Cooler ON (Set Thermostat Status to Cooling).

Edit Remove	Yes	Heater ON	Temperature Monitor Temperature <= 0.0 °C	Set Thermostat 1 Status to Heating Set Thermostat 2 Status to Heating Set Thermostat 3 Status to Heating
Edit Remove	Yes	Cooler ON	Temperature Monitor Temperature >= 20.0 °C	Set Thermostat 1 Status to Cooling Set Thermostat 2 Status to Cooling Set Thermostat 3 Status to Cooling

Figure.II.26: Temperature Monitor Automation Conditions

Edit Remove	Yes	Auto Heat Temperature	PTT0810ASE8- Temperature is between 0 and 4	Set PTT0810NH56- Auto Heat Temperature to 10 Set Thermostat 2 Auto Heat Temperature to 10.0 °C Set Thermostat 3 Auto Heat Temperature to 10.0 °C
Edit Remove	Yes	Auto Cool Temperature	PTT0810ASE8- Temperature is between 13 and 20	Set PTT0810NH56- Auto Cool Temperature to 10 Set Thermostat 2 Auto Cool Temperature to 10.0 °C Set Thermostat 3 Auto Cool Temperature to 10.0 °C

Figure.II.27: Auto Temperature Monitor Automation Conditions

❖ Humidity Monitoring System

Comprising a humidity sensor and humidifier, this setup maintains appropriate moisture in the greenhouse air. When humidity drops below a certain threshold, the humidifier is activated to sustain conditions that favor plant health and prevent excessive dryness.

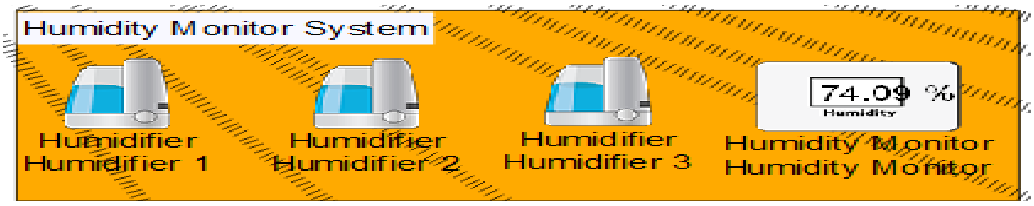

Figure.II.28: Humidity Monitor System

➢ Role & Purpose:

- Detects greenhouse humidity and activates a humidifier when levels drop.
- Prevents plants from wilting due to dryness.

➢ Automation Example:

- Condition: If Humidity < =60%,
- Action: Turn Humidifier ON (Set Humidifier Status to ON).
- Condition: If Humidity goes above 80%,
- Action: Turn Humidifier OFF to avoid excessive moisture.

Edit Remove	Yes	Humidifier ON	Humidity Monitor Humidity <= 60 %	Set Humidifier 1 Status to true Set Humidifier 2 Status to true Set Humidifier 3 Status to true
Edit Remove	Yes	Humidifier OFF	Humidity Monitor Humidity >= 80 %	Set Humidifier 1 Status to false Set Humidifier 2 Status to false Set Humidifier 3 Status to false

Figure.II.29: Humidity Monitor Automation Conditions

❖ Smoke Detector System

Featuring a smoke detector, sprinkler, and siren, this system detects smoke and responds promptly to potential fires. The detector triggers an alarm and activates the sprinkler, helping to mitigate fire damage and ensure safety within the greenhouse.

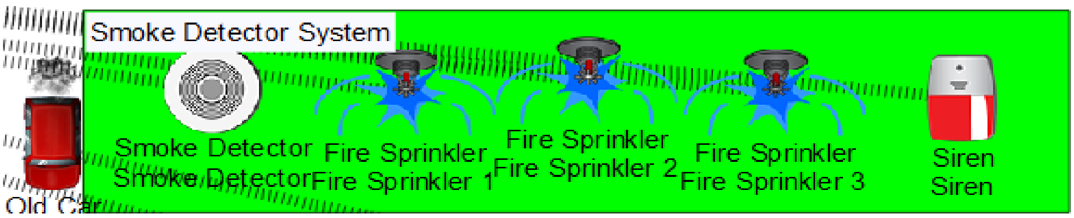

Figure.II.30: Smoke Detector System

➢ **Role & Purpose:**

- Detects smoke/fire hazards.
- Immediately triggers alarms and sprinklers to contain fire.

➢ **Automation Example:**

- Condition: If Smoke Detector Level ≥ 0.1,
- Action: Turn Fire Sprinkler ON and Siren ON.
- Condition: Once smoke level is approximately zero,
- Action: Turn Sprinkler OFF and reset alarms.

Edit Remove	Yes	Fire Sprinkler ON	Smoke Detector Level >= 0.1	Set Siren On to true Set Fire Sprinkler 1 Status to true Set Fire Sprinkler 2 Status to true Set Fire Sprinkler 3 Status to true
Edit Remove	Yes	Fire Sprinkler OFF	Smoke Detector Level < 0.06	Set Fire Sprinkler 1 Status to false Set Fire Sprinkler 2 Status to false Set Siren On to false Set Fire Sprinkler 3 Status to false

Figure.II.31: Smoke Detector Automation Conditions

❖ **Light System**

Designed to provide and control artificial lighting, this system uses lamps that can switch on or off automatically. It can be triggered by valid RFID access or based on ambient light conditions, ensuring adequate illumination while conserving energy.

Figure.II.32: Light System

➢ **Role & Purpose:**

- Provides supplemental lighting in low-light conditions or upon valid access.
- Ensures plants get enough light for photosynthesis.

➢ **Automation Example:**

- Condition: If Door is Unlocked (valid RFID) or Motion Detector is triggered,
- Action: Turn Lamp ON (Set Lamp 1 Status to ON).
- Condition: If no motion or door is locked,
- Action: Turn Lamp OFF to save energy.

Edit Remove	Yes	Lamp OFF	Door Lock is Lock	Set Lamp 3 Status to Off

Figure.II.33: Light System Automation Conditions

❖ **Security System**

Using RFID cards and a reader, this system controls entry to the greenhouse. If a valid card is detected, the door unlocks and alarms remain off; if invalid, the door stays locked and Webcam activate and a siren may activate. This safeguards the greenhouse from unauthorized access.

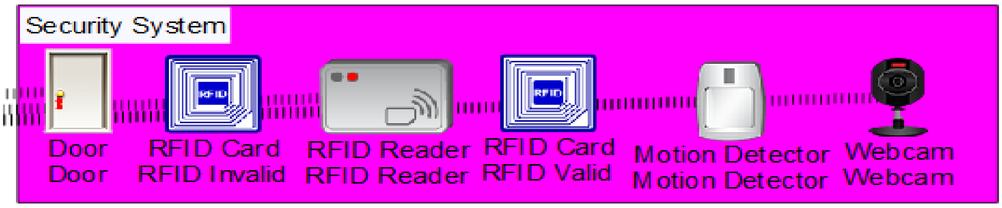

Figure.II.34: Security System RFID Invalid

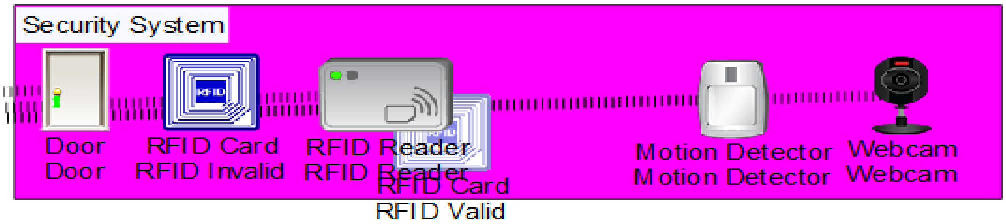

Figure.II.35: Security System RFID Valid

- **Role & Purpose:**
  - Protects the greenhouse from unauthorized entry using RFID, motion sensors, webcam, and door locks.
  - Alerts with sirens if suspicious activity is detected.
- **Automation Example:**
  - Condition: If RFID Reader Status is Invalid AND Motion Detector is True,
  - Action: Lock Door and Set Siren ON.
  - Condition: If RFID Reader is Valid,
  - Action: Unlock Door (and possibly turn on lights).

Edit Remove	Yes	Motion ON	Match all: • Motion Detector On is true • RFID Reader Status is Invalid	Set Siren On to true
Edit Remove	Yes	Motion OFF	Motion Detector On is false	Set Siren On to false

Figure.II.36: Motion Automation Conditions

Edit Remove	Yes	RFID Invalid	RFID Reader Card ID != 1001	Set RFID Reader Status to Invalid
Edit Remove	Yes	Door Unlock	RFID Reader Status is Valid	Set PTT08103XZ0- Lock to 0 Set Siren On to false Set Lamp 3 Status to On Set Webcam On to true
Edit Remove	Yes	RFID Valid	RFID Reader Card ID = 1001	Set RFID Reader Status to Valid
Edit Remove	Yes	Door Lock	RFID Reader Status is Invalid	Set PTT08103XZ0- Lock to 1 Set Webcam On to true

Figure.II.37: Security System Automation Conditions

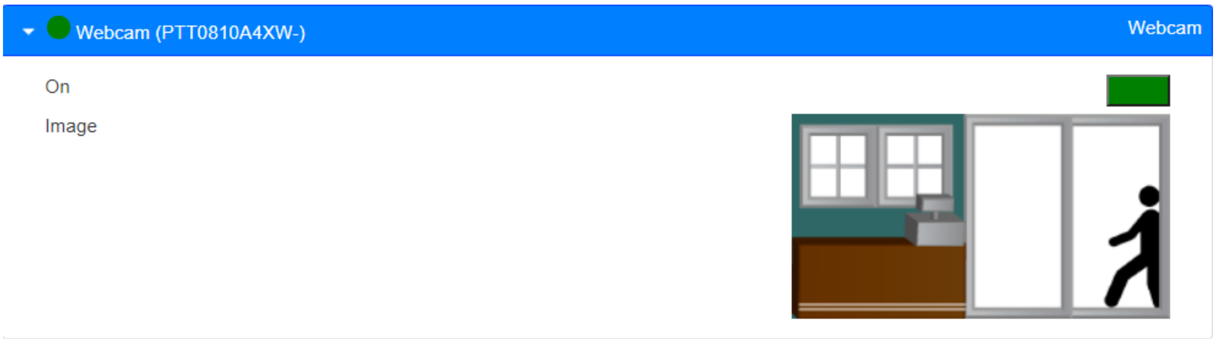

Figure.II.38: Webcam surveillance

❖ CO_2 Detector System

A CO_2 sensor measures carbon dioxide levels, essential for photosynthesis. If concentrations rise above acceptable limits, an exhaust fan is engaged to lower CO_2 and maintain a stable environment for plant growth.

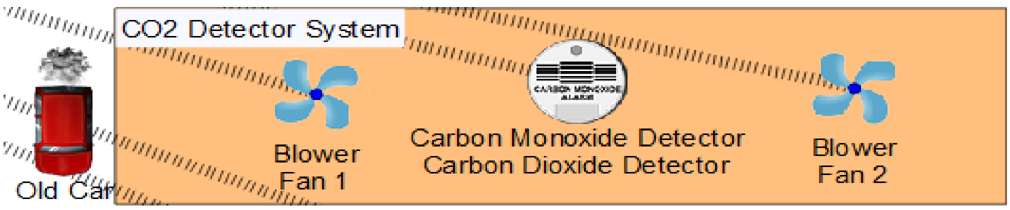

Figure.II.39: CO2 Detector System

➢ **Role & Purpose:**

- Monitors carbon dioxide concentration vital for photosynthesis.
- Activates ventilation (fans) when CO_2 is too high.

➢ **Automation Example:**

- Condition: If CO_2 Level is High (e.g., > = 2),
- Action: Turn Fan ON (possibly at high speed).
- Condition: If CO_2 is Moderate,
- Action: Set Fan to low speed.

- Condition: If CO_2 is Normal,
- Action: Fan OFF to conserve energy.

Edit Remove	Yes	CO2 Level Large	Carbon Dioxide Detector Level >= 2	Set Fan 1 Status to High Set Fan 2 Status to High
Edit Remove	Yes	C02 Level Medium	Carbon Dioxide Detector Level is between 0.12 and 1	Set Fan 1 Status to Low Set Fan 2 Status to Low
Edit Remove	Yes	C02 Level Low	Carbon Dioxide Detector Level <= 0.01	Set Fan 1 Status to Off Set Fan 2 Status to Off

Figure.II.40: CO2 Detector Automation Conditions

❖ Solar Power System

This setup includes a solar panel, power meter, and battery. Solar energy is converted into electricity and stored in the battery, reducing reliance on external power sources and promoting eco-friendly operation for the entire greenhouse system.

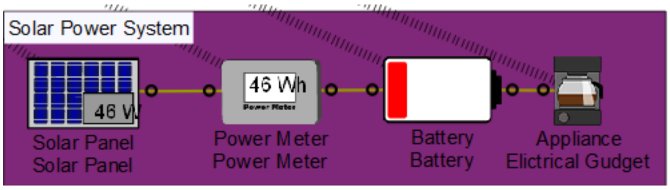

Figure.II.41: Solar Power System

➢ Role & Purpose:

- Uses solar panels, a power meter, and battery to generate and store energy.
- Supplies clean electricity to greenhouse devices.

➢ Automation Example:

- Condition: If Power Meter shows battery > 30%,
- Action: Turn On Electrical Gadget (Set Electrical Gadget On).
- Condition: If battery < 30%,
- Action: Gadget OFF to conserve stored power.

Edit Remove	Yes	appliance on	Match all: • battery Available power > 30 % • solar panel Status > 30 Wh • power meter Status > 30 Watts	Set electric gadget On to true
Edit Remove	Yes	appliance off	Match all: • PTT081093YT- Light < 30 • solar panel Status < 30 Wh • power meter Status < 30 Watts • battery Available power < 30 %	Set electric gadget On to false

Figure.II.42: Solar Power Automation Conditions

II.5 Conclusion

In this chapter, we built and configured an IoT-based smart greenhouse monitoring system using Cisco Packet Tracer, focusing on network infrastructure and device integration. The setup included routers, switches, an IoT server, a home gateway, and various sensors, all working together to monitor and control greenhouse conditions remotely.

We implemented DNS and DHCP for network automation, ensuring that devices receive the correct configurations dynamically. Remote access was also set up, allowing laptops and smartphones to control the system from anywhere. The use of IoT sensors for temperature, humidity, CO_2 levels, and security demonstrated how networked automation enhances agricultural efficiency by optimizing irrigation, climate control, and security measures.

This project highlights the role of networking in IoT-based smart agriculture, where efficient communication between devices enables automation and real-time decision-making. Future improvements could include AI-driven monitoring, LoRaWAN for extended coverage, and renewable energy integration, making the system more scalable and resilient. From a networking perspective, this project proves that solid network design is the backbone of effective IoT deployment in precision agriculture.

CHAPTER III

IoT Plant watering system using ESP8266 and Blynk

III.1 Introduction

This chapter will describe in detail how to make a plant watering system with the Nodemcu ESP8266 board and the new Blynk update. For that, I mainly used a soil moisture sensor and a relay module. We can get the moisture values using the soil moisture sensor and we can control the water pump using the relay module.

In this project, I used a mini water pump as an example. Also, we can control and monitor this system on our smartphone or computer using the Blynk platform from anywhere in the world. this is a low-cost project, more helpful for our home garden, small greenhouses and educational projects.

III.2 Hardware Components

Hardware components are the core physical devices that form an IoT-based smart irrigation system, enabling data collection, processing, and automation. These components work together to monitor environmental conditions, analyze data, and automate irrigation processes, ensuring efficient water management and optimized crop growth. This section provides a detailed overview of these key hardware components, their functions, and their role in creating a fully automated and intelligent irrigation system [24].

III.2.1 Nodemcu Esp8266:

NodeMCU is an open-source firmware developed for Wi-Fi-enabled microcontrollers like the ESP8266 and ESP32 by Espressif. It supports the Lua programming language and uses a lightweight file system called SPIFFS to store data in the module's internal flash memory.

The ESP8266 is a low-cost, highly integrated microcontroller unit (MCU) with built-in Wi-Fi capabilities, making it ideal for Internet of Things (IoT) applications. It offers a reliable and energy-efficient solution for wireless communication in smart devices [25].

Figure.III.1 : Nodemcu Esp8266

III.2.2 Soil moisture sensor :

A resistive sensor that measures soil moisture by detecting electrical conductivity between two probes. It outputs both analog (variable moisture level) and digital (threshold-based) signals, making it ideal for low-cost, real-time irrigation control.

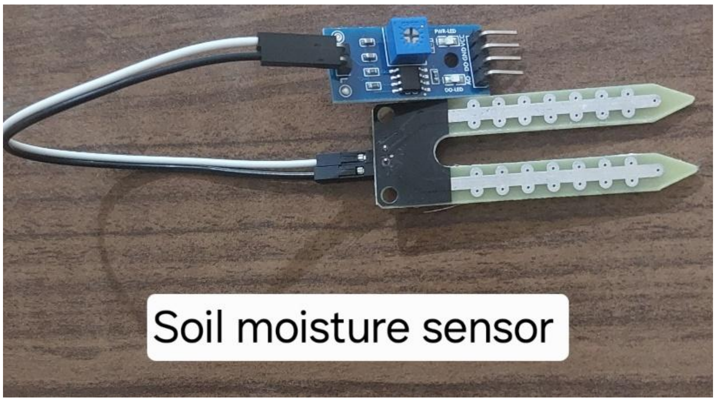

Figure.III.2: Soil moisture sensor

III.2.3 Relay module:

A relay module functions as an electrically operated switch that allows a low-power control signal (from microcontrollers like Arduino or ESP8266) to manage a higher-power circuit (such as a motor or pump) safely. It features built-in circuit protection, including transistors, diodes, and often optocouplers, ensuring galvanic isolation between the control and load sides. This design guards the sensitive electronics from voltage spikes, noise, and potential ground loop issues, enhancing system safety and reliability.

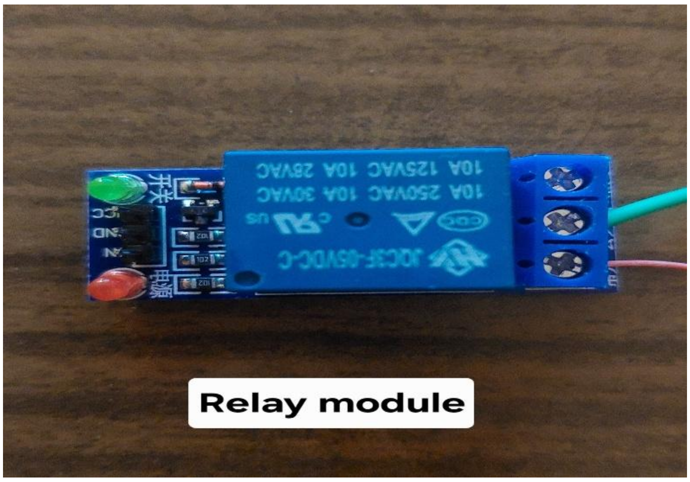

Figure.III.3: Relay module

III.2.4 LCD display:

The 16x2 LCD display (Liquid Crystal Display) shows real-time soil moisture levels in percentage format, offering visual feedback for users. It displays 2 rows of 16 characters each, where each character is built from a matrix of 5x8 pixels.

To simplify wiring and save microcontroller GPIO pins.

This module operates typically at 5V and communicates using the I2C protocol with a unique address (usually 0x27 or 0x3F). It is ideal for embedded systems where display readability and wiring simplicity are important.

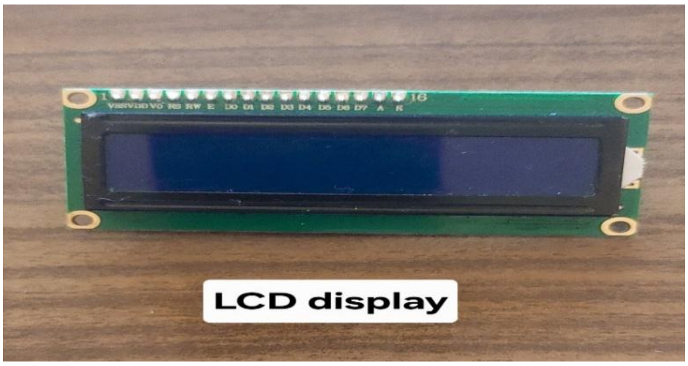

Figure.III.4: LCD display

III.2.5 I2C module:

The I2C (Inter-Integrated Circuit) module is a widely used two-wire serial communication protocol that connects microcontrollers to low-speed peripherals such as LCD displays, sensors, and EEPROMs. It uses just two lines:

- SDA (Serial Data)
- SCL (Serial Clock)

I2C supports multi-master and multi-slave configurations, allowing multiple devices to communicate over the same bus with unique addresses. This reduces wiring complexity and simplifies hardware integration in embedded IoT systems like smart irrigation.

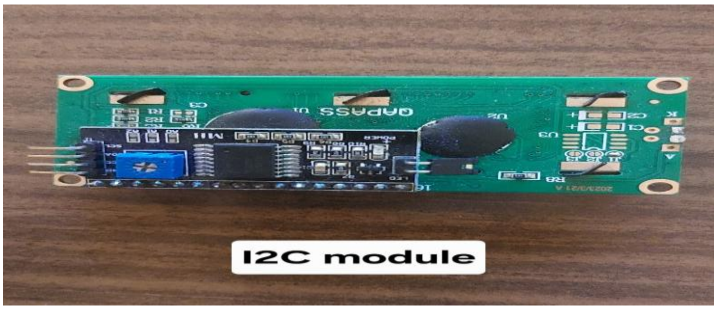

Figure.III.5: I2C module

III.2.6 Breadboard:

A breadboard is a reusable prototyping platform for building and testing electronic circuits without soldering. It consists of a grid of interconnected holes (or "tie points") with internal metal clips, allowing components and wires to be inserted and connected temporarily.

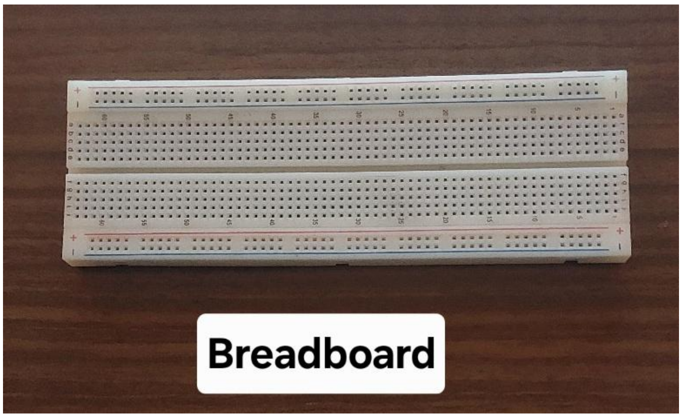

Figure.III.6: Breadboard

III.2.7 Male to Female jumper wires:

Male-to-female jumper wires are flexible insulated cables with pre-crimped connectors used to establish temporary electrical connections in prototyping and testing circuits.

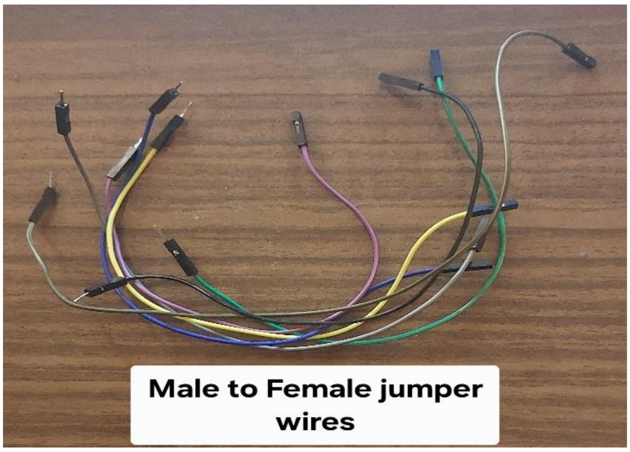

Figure.III.7: Male to Female jumper wires

III.2.8 Male to Male jumper wires:

Male-to-male jumper wires are insulated cables with male pins (0.1" pitch) on both ends,used to create temporary electrical connections between components with female headers (e.g., breadboards, microcontrollers, or sensor modules). They are essential for prototyping and testing circuits without soldering.

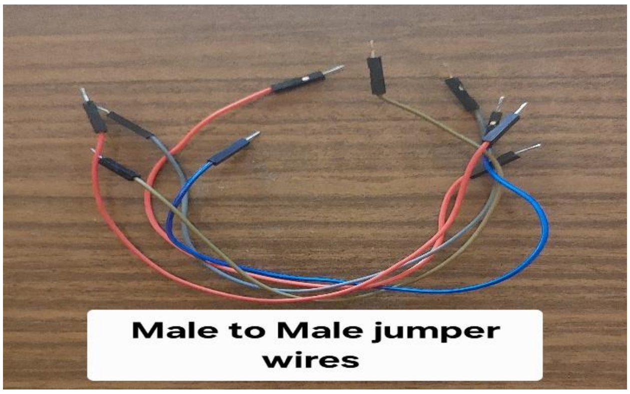

Figure.III.8: Male to Male jumper wires

III.2.9 Mini water pump:

A mini water pump is a compact, low-power device designed to move small volumes of water or other liquids. It is commonly used in DIY (Do-It-Yourself) projects, automation systems, and portable applications.

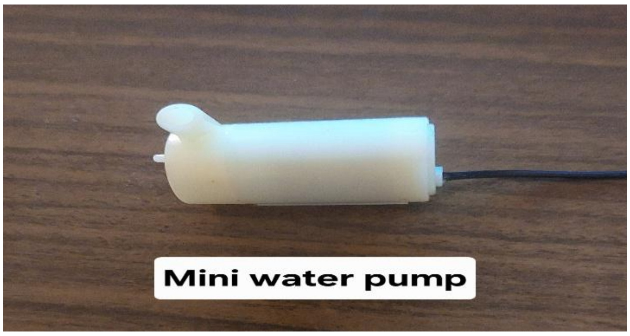

Figure.III.9: Mini water pump

III.2.10 Mini water pipe:

A mini water pipe is a small-scale piping system designed to transport water or other liquids in compact applications.

Figure.III.10: Mini water pipe

III.2.11 9V battery:

A 9V battery is a compact, rectangular DC power source widely used in low-power electronics and prototyping applications. It typically provides a direct current (DC) output of 9 volts, making it suitable for powering microcontrollers like the NodeMCU, sensors, small pumps, and other peripheral modules in standalone or portable IoT systems. Its portability and ease of connection make it ideal for testing and small-scale automation setups.

Figure.III.11: 9V battery with clippers

III.3 Implementation

Placing the Nodemcu board on the breadboard and connect the VIN and GND pins to the breadboard.

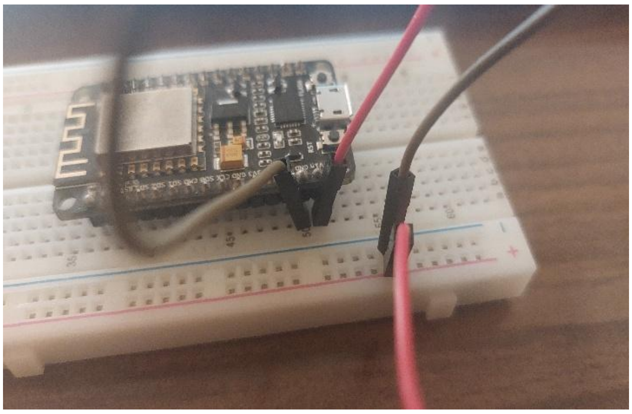

Figure.III.12: Placing Nodemcu 8266

Placing the soil moisture sensor on the breadboard and connect it to the Nodemcu board. Using this circuit diagram below:

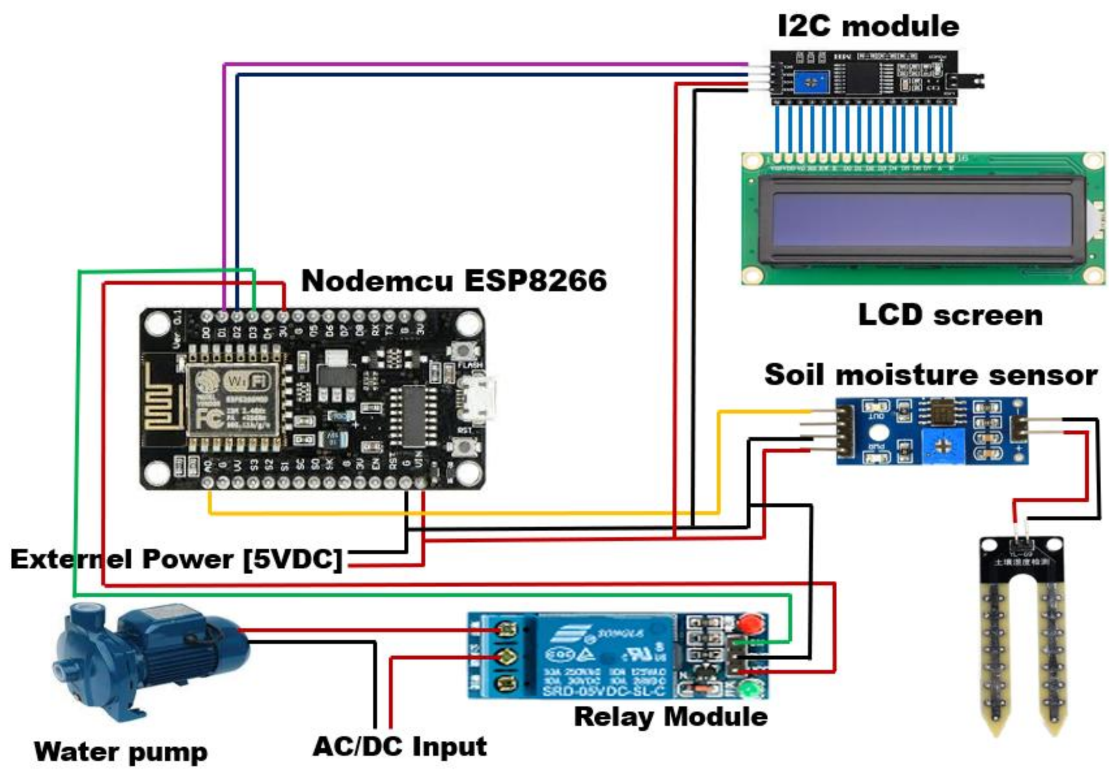

Figure.III.13: circuit diagram

Connect the VCC and GND pins to the breadboard, and A0→A0.

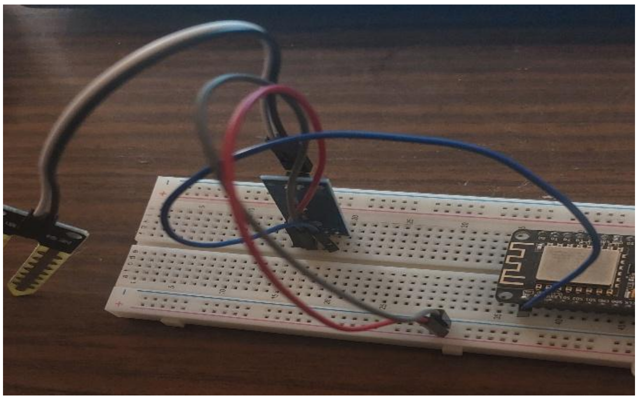

Figure.III.14: Placing soil moisture sensor

Connecting the LCD display to the Nodemcu board by connect the VCC and GND pins to the breadboard, and SDA →D2, SCL→D1.

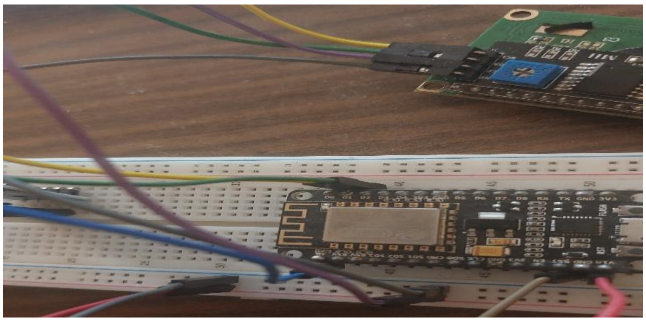

Figure.III.15: Connecting LCD display to Nodemcu 8266

Connecting the Relay module to the Nodemcu board by connect the GND pin to the breadboard, and IN →D3, VCC→3V3, after that we connect battery clippers and Mini water pump with the Relay module.

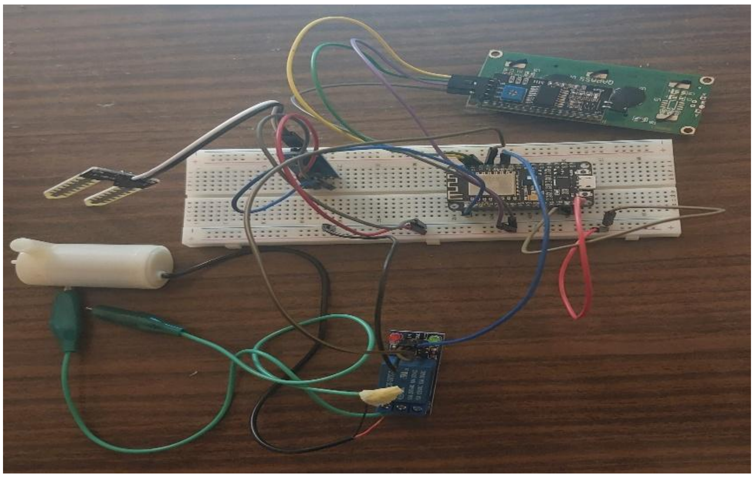

Figure.III.16: Connecting Relay Module to Nodemcu 8266

III.4 Blynk web dashboard

Creating the Blynk web dashboard by entering the Blynk website and creating new account signing in and clicking new template button [26].

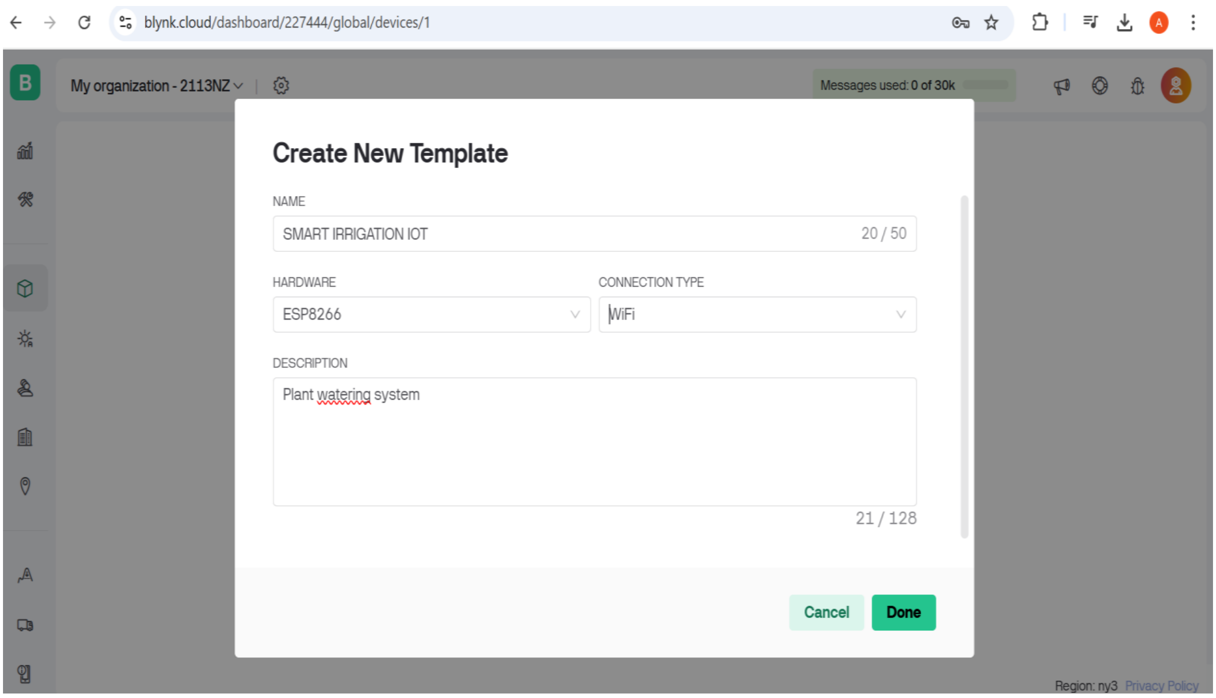

Figure.III.17: Create Blynk Template

Now clicking the "Datastreams" tab and create two data streams Using the information bellow:

- **Virtual PIN –> Name – Moisture value / PIN — V0 / MIN — 0 / MAX — 100**
- **Virtual PIN –> Name – Water pump / PIN — V1 / MIN — 0 / MAX — 1**

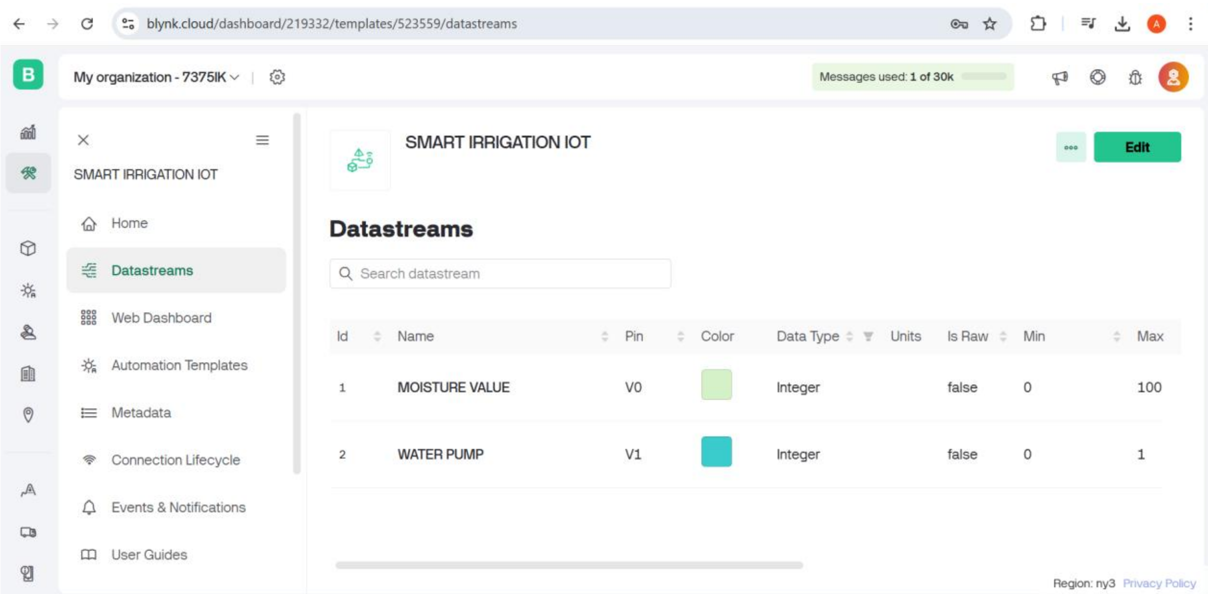

Figure.III.18: Create Moisture Value & Water Pump Pins

Next, clicking the “Web dashboard” tab and include the one button and one Gauge widget to the dashboard. And then, arrange these widgets, now clicking the one-by-one settings buttons on these widgets and select the data streams we created earlier.

Then, click the save button.

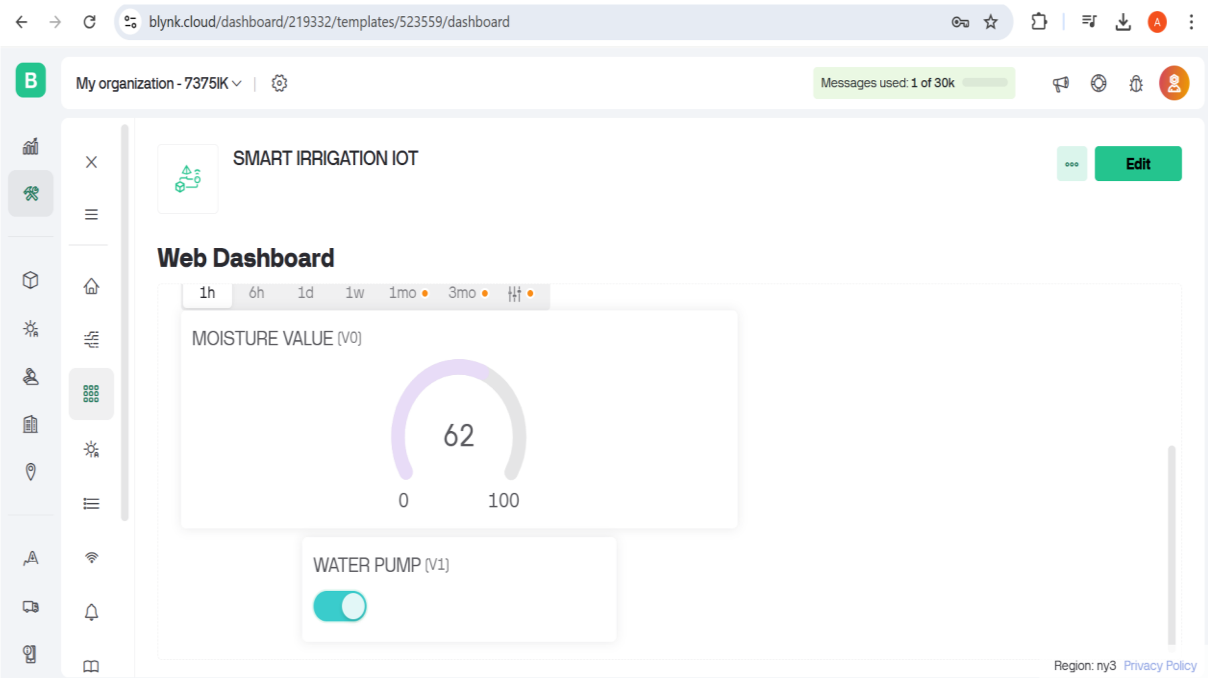

Figure.III.19: Create Moisture Value & Water Pump Widgets

Next clicking the search icon button and create a “New device”. For that, selecting the template created earlier. And the web Dashboard has been created.

III.5 Programing

Starting project with connecting to the computer

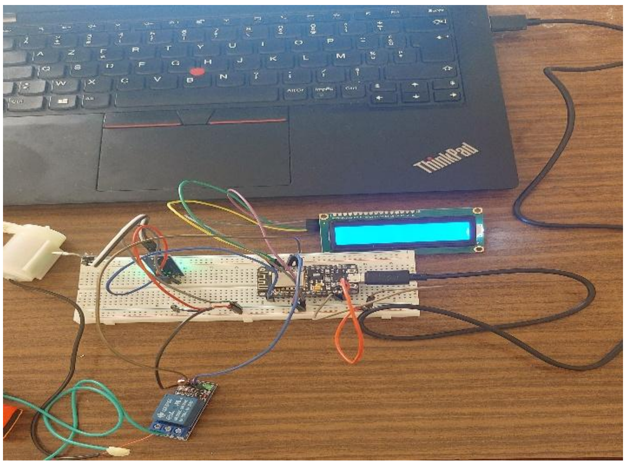

Figure.III.20: Project Connection

Next, download Arduino IDE " https://www.arduino.cc/en/software "

There are few libraries necessary for the project below

ESP8266 WIFI library → " https://drive.google.com/file/d/1b-tHjcqBHVCgQKabdR19iGmo4E-pa2mW/view?usp=sharing "

Blynk library → " https://drive.google.com/file/d/1dbCZECyzjI7zxE_Q136jA9--dHELAGNt/view?usp=sharing "

I2C library →" https://drive.google.com/file/d/15-vg0hSKDJ9EafxvWnjkg-o3WERHccBx/view?usp=sharing "

And the Program of this Project →
https://drive.google.com/drive/folders/1v0YH2yG522vQEEK3Y5ZLsB5qBFJOjNrU?usp=sharing

Now copy and paste the Blynk auth token. It's in the Blynk web dashboard.

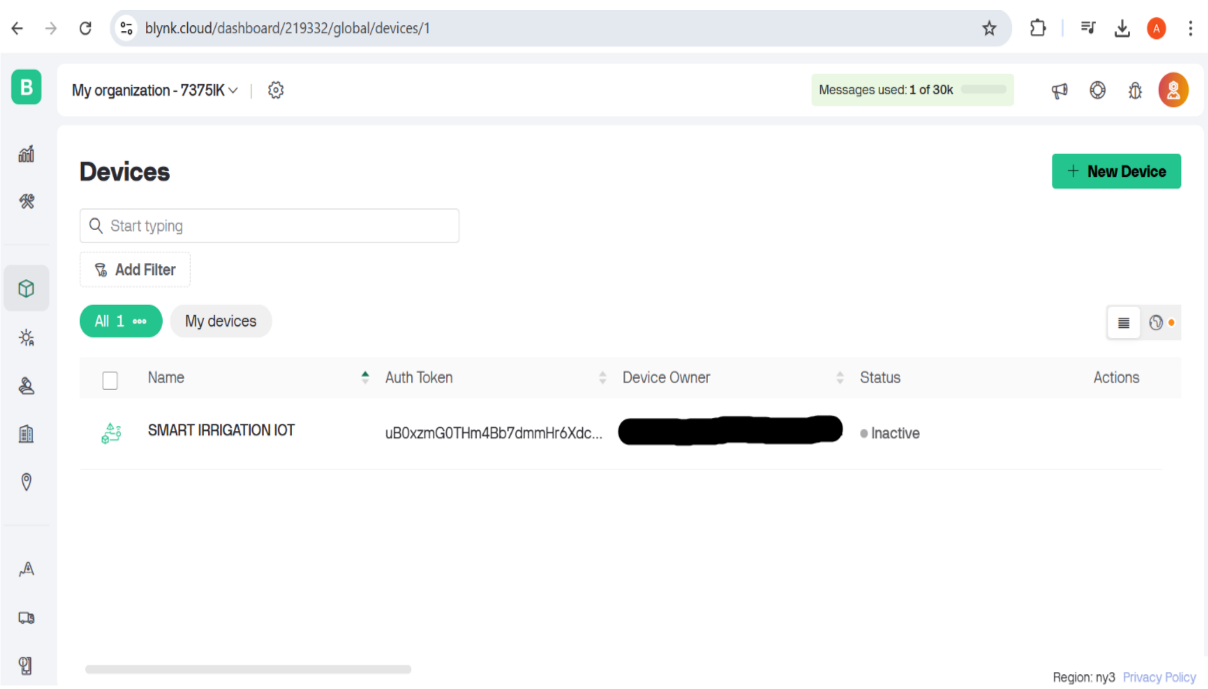

Figure.III.21: Copy Auth Token

Next, entering WIFI SSID and password. And then, select board and port. Finally, upload this code to the Nodemcu board [27].

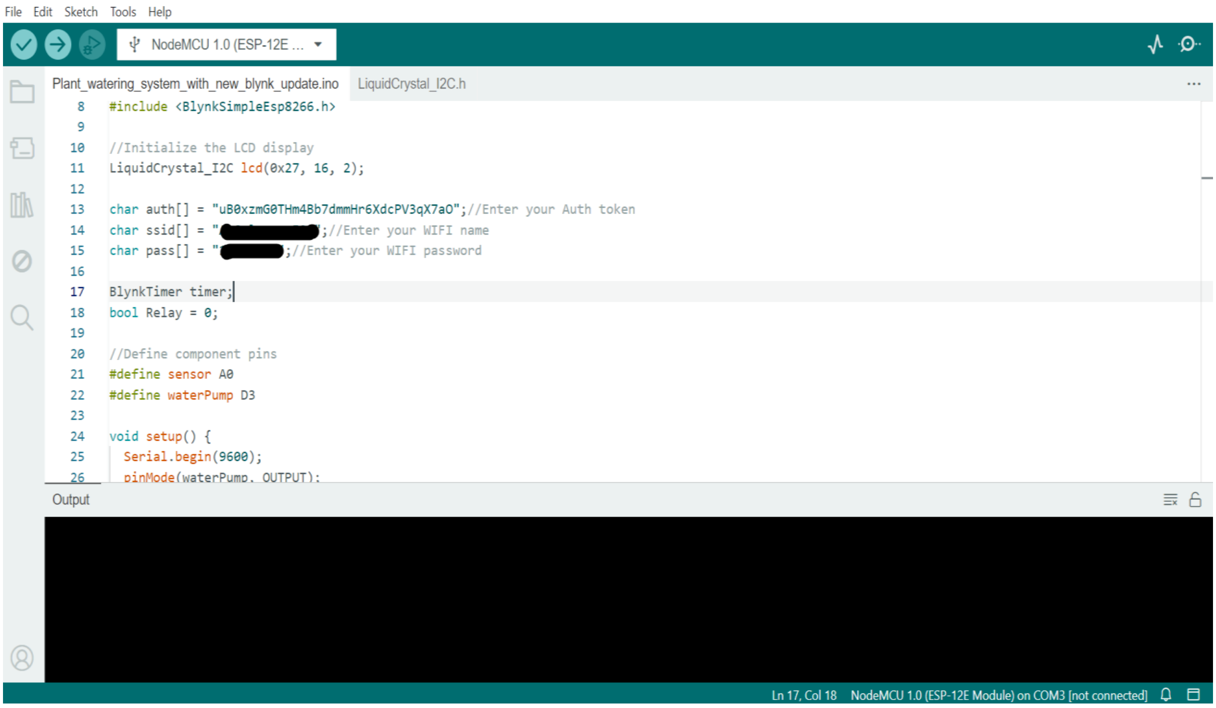

Figure.III.22: Paste Auth Token and Connection to WIFI

III.6 Blynk Mobile dashboard

First, download and install the Blynk app on the phone. Then, sign in to the account and click the template created in the Blynk web dashboard.

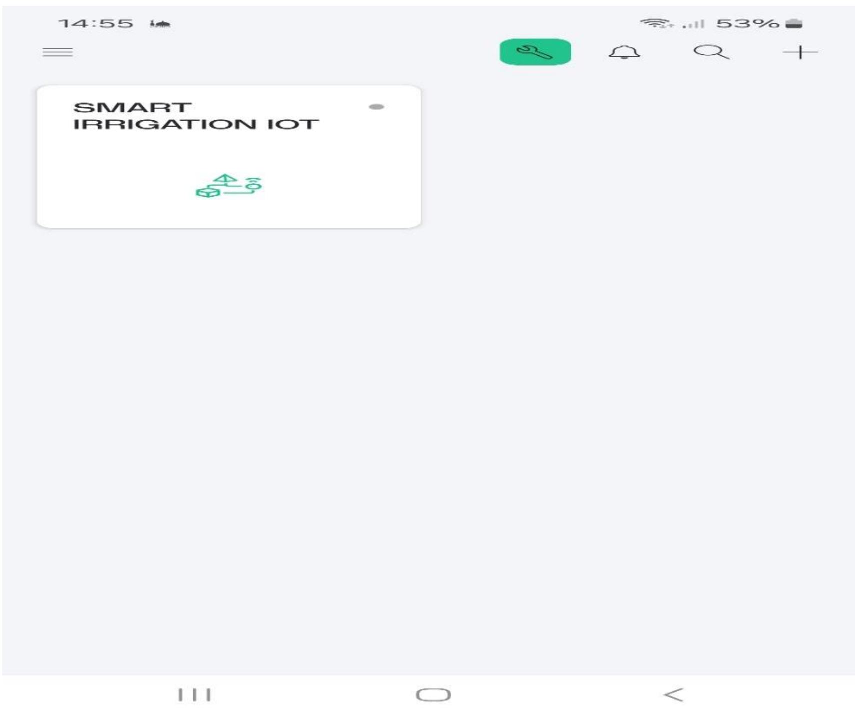

Figure.III.23: Sign in Blynk Mobile

Now, adding the widget to the dashboard. For that clicking the + icon at the top right corner.

And then, adding one button and one gauge widget to the dashboard.

After arranging these widgets as liked. Now, clicking the one-by-one widget and select the datastreams created in the Blynk web dashboard.

Figure.III.24: Add in Blynk Mobile Widgets

OK, the Blynk mobile dashboard is ready.

Connecting to WIFI

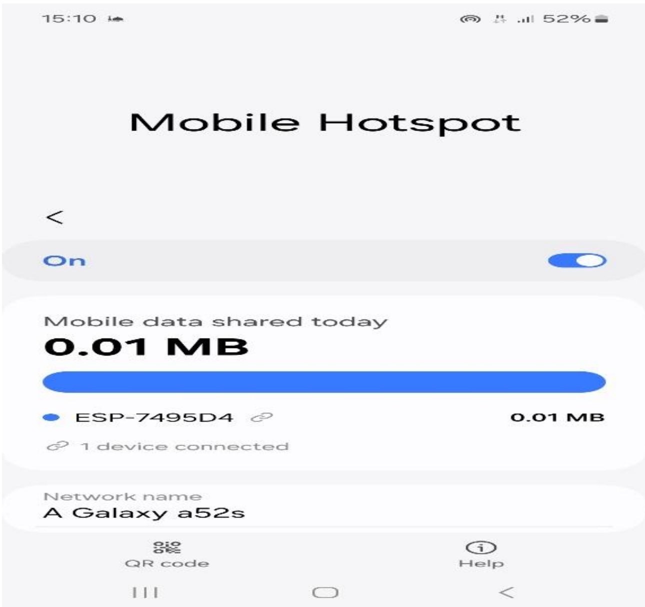

Figure.III.25: WIFI Connection

Project Is ON

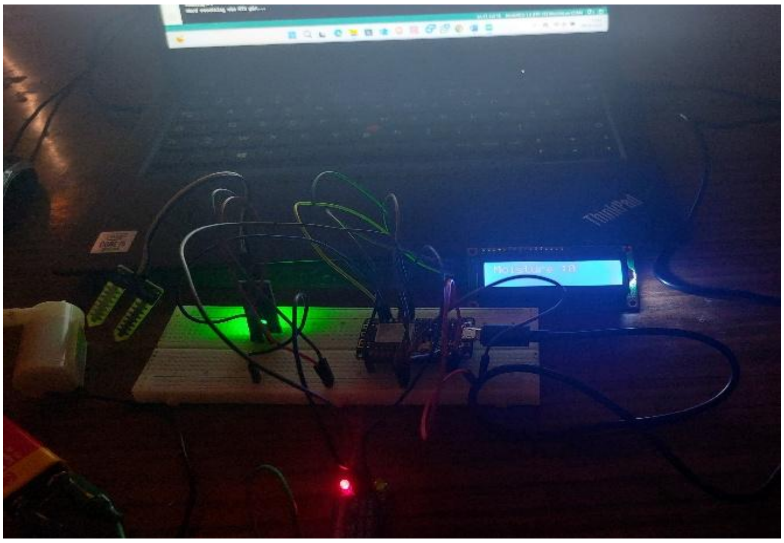

Figure.III.26: Working Project

Testing

Figure.III.27: Test Project in Wet Soil

After putting the soil sensor in we read on phone that moisture level is 0 so we click ON for the Mini water pump to start, after the soil becomes wet enough to reach the moisture level needed we click on OFF to stop the Mini water pump as shown in image above. And here is example what it looks like on dry soil.

Figure.III.28: Test Project in Dry Soil

III.7 Conclusion

In this chapter, we successfully designed and implemented an IoT-based plant watering system using the NodeMCU ESP8266 board and the Blynk platform. The system integrates a soil moisture sensor and a relay module to automate the activation of a mini water pump, ensuring optimal irrigation based on real-time soil moisture levels. By leveraging Blynk's web and mobile dashboards, users can monitor and control the system remotely, enhancing convenience and efficiency.

The practical implementation demonstrated the effectiveness of IoT in precision agriculture, reducing water wastage while maintaining plant health. The use of Arduino IDE for programming, coupled with WiFi connectivity, highlights the potential of low-cost, scalable solutions for smart irrigation. This system can be further expanded by integrating additional sensors, AI-based predictive analytics, and solar power to improve sustainability and automation.

GENERAL CONCLUSION

General Conclusion:

Agriculture remains the backbone of food security, yet it faces unprecedented challenges due to climate change, water scarcity, and the need for increased efficiency. Traditional irrigation techniques, while widely used, often result in significant water wastage and inefficient resource allocation. The emergence of Internet of Things (IoT) technology has provided a transformative solution by enabling real-time monitoring, automated control, and remote access to irrigation systems.

This thesis explored the design and implementation of an IoT-based smart irrigation system, focusing on precision water management to optimize resource utilization while ensuring optimal plant growth. Through Cisco Packet Tracer simulations and practical deployment of a NodeMCU ESP8266-based plant watering system, we demonstrated the potential of IoT in automating greenhouse monitoring and irrigation processes.

The Cisco Packet Tracer-based smart greenhouse monitoring system was designed to remotely manage environmental parameters such as temperature, humidity, soil moisture, CO_2 levels, and security. Using a structured network architecture comprising routers, switches, IoT servers, and a home gateway, the system enables seamless communication between sensors, actuators, and user devices. The implementation of DNS, DHCP, and remote access configurations ensured secure and scalable connectivity, allowing users to control greenhouse operations via a laptop or smartphone.

Complementing the simulation, the practical implementation of an ESP8266-based automated irrigation system showcased real-world IoT applications. The system utilized a soil moisture sensor and relay module to control a mini water pump, which could be monitored and operated remotely via the Blynk cloud platform. This demonstrated how low-cost IoT solutions can improve water efficiency, reduce labor costs, and enhance agricultural productivity.

The results of this research emphasize the importance of integrating IoT in agriculture, offering numerous advantages such as:

- Water conservation through real-time soil moisture monitoring.
- Remote access and automation, reducing human intervention.
- Scalability for both small-scale greenhouses and large farms.

- Integration of smart security and climate control systems.

However, despite the numerous benefits, several challenges and future research directions remain. Cybersecurity concerns, network reliability, and large-scale IoT deployment costs need to be addressed. Additionally, integrating AI-driven predictive analytics, LoRaWAN for extended connectivity, and renewable energy sources can further enhance the system's efficiency and sustainability.

In conclusion, this thesis has demonstrated that IoT-based smart irrigation systems represent a crucial step forward in modernizing agriculture. By leveraging sensor networks, cloud computing, and automation, we can move towards a future where precision agriculture optimizes resource management, increases food production, and supports sustainable development. This research serves as a foundation for further innovations in smart farming, with the potential to revolutionize agricultural practices globally.

Outlook

Looking ahead, several enhancements can be explored to improve the efficiency and scalability of IoT-based smart irrigation systems:

1. AI and Machine Learning Integration
   - Predictive analytics for dynamic irrigation scheduling based on weather forecasts and soil conditions.
   - Automated crop health monitoring using image recognition and AI models.
2. Expanded Connectivity & Security
   - Implementation of LoRaWAN or 5G for broader, low-power connectivity.
   - Strengthening cybersecurity measures to protect IoT networks from potential threats.
3. Renewable Energy Integration
   - Powering IoT devices with solar panels to improve energy efficiency and sustainability.
   - Smart energy management systems to optimize battery usage.

4. Scalability for Large-Scale Agriculture
    - Adapting the system for large farms by integrating more sensors, automated drones, and cloud computing.
    - Developing an edge computing model to reduce reliance on constant internet connectivity.

By implementing these advancements, IoT-based smart irrigation systems can play a crucial role in addressing global food security challenges, reducing water consumption, and promoting sustainable agriculture. This research lays the foundation for future innovations that can revolutionize farming practices worldwide.

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