OEL REPORT: Design and Implementation of a Scalable IIUI University Network Using Subnetting and TCP/IP Protocols

1. Project Overview

This report presents the detailed design and implementation of a scalable, multi-building network infrastructure for the International Islamic University Islamabad (IIUI) campus. The project holds significant importance as it aims to enhance the university's academic and administrative capabilities by providing a reliable, high-performance network. The network facilitates seamless communication across departments, ensures efficient resource sharing, and enables centralized management. By incorporating advanced subnetting techniques, VLAN segmentation, and routing protocols, the design addresses both current and future needs of the university. The network's scalability ensures that new buildings and departments can be integrated effortlessly, while its robust security measures protect sensitive academic and administrative data. This infrastructure plays a pivotal role in supporting the university's transition into a digitally connected and collaborative environment, fostering innovation and efficiency in academic pursuits.

2. Network Design Requirements

Subnetting and VLANs were chosen as foundational elements of the network design to address critical requirements such as scalability, efficient resource utilization, and performance optimization. Subnetting ensures the logical division of the IP address space, minimizing wastage while providing sufficient addresses for each department and user group. This structured approach supports the addition of new departments or devices without the need for major reconfiguration.

VLANs, on the other hand, facilitate traffic segmentation by isolating network segments according to departments and user roles. This isolation enhances security by limiting the scope of broadcast domains and reducing the risk of unauthorized access. Additionally, VLANs improve performance by minimizing unnecessary traffic across the network, thus reducing congestion and latency.

By combining subnetting with VLANs, the network achieves a high degree of flexibility and control, enabling centralized management while ensuring that departmental networks can operate independently. This dual approach also lays the groundwork for implementing advanced routing protocols and security policies, further enhancing the network's robustness and adaptability.

2.1 Subnetting and IP Address Allocation

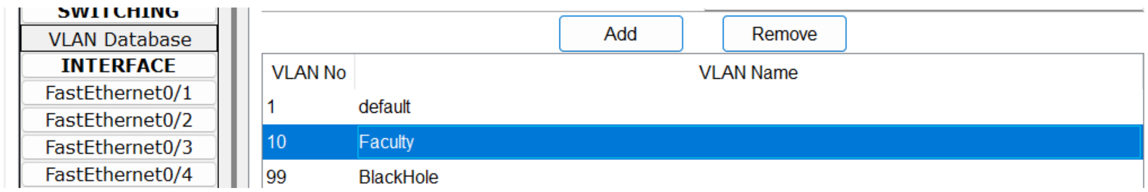
The network uses private IP addressing, ensuring efficient utilization of the available IP space while accommodating future growth.

Subnet Details:

Each subnet is assigned a specific range of IP addresses tailored to its user group or department, ensuring efficient IP space utilization and ease of management:

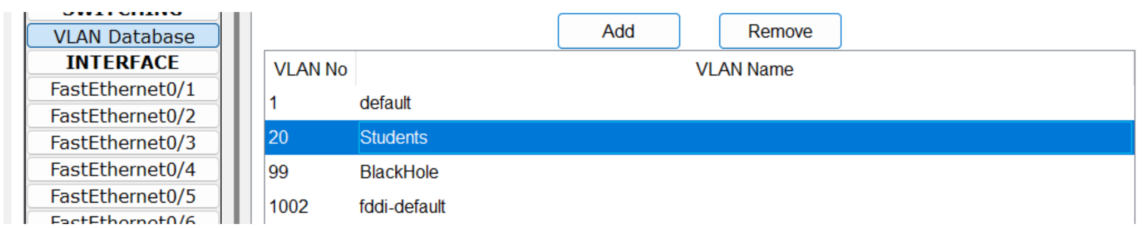
- **Department of Electrical and Computer Engineering:**
    - VLAN 10 (Faculty and Labs): 172.16.1.0/25

```
Faculty-SW(config)#vlan 10
Faculty-SW(config-vlan)# name Faculty
Faculty-SW(config-vlan)#
```



Allocated for faculty and lab resources to ensure dedicated bandwidth and security. Subnet /25 provides 126 usable IPs, sufficient for the expected number of devices while reserving additional space for growth.

- VLAN 20 (Students): 172.16.1.128/25

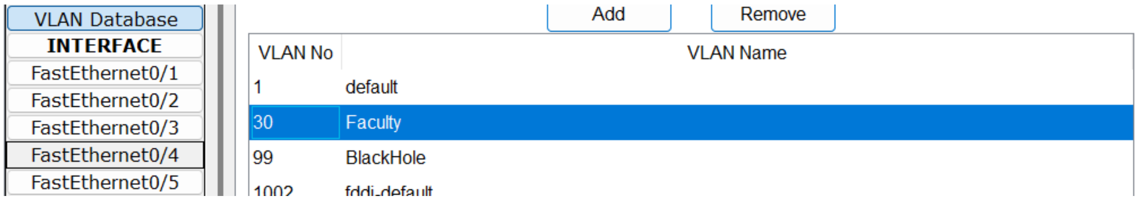



```
Student-SW(config)#
Student-SW(config)#vlan 20
Student-SW(config-vlan)# name Students
Student-SW(config-vlan)#
```

Dedicated for student devices, ensuring traffic segregation from faculty and labs.

Subnet /25 isolates student traffic and prevents broadcast domain overlap.

- **Department of Social Sciences:**
    - VLAN 30 (Faculty and Labs): 172.16.2.0/25




```
Faculty-SW(config)#
Faculty-SW(config)#vlan 30
Faculty-SW(config-vlan)# name Faculty
Faculty-SW(config-vlan)#
```

Segregates faculty and lab resources from other departments for efficient management.

Allocated for faculty and lab resources to ensure dedicated bandwidth and security. Subnet /25 provides 126 usable IPs, sufficient for the expected number of devices while reserving additional space for growth.

- VLAN 40 (Students): 172.16.2.128/25

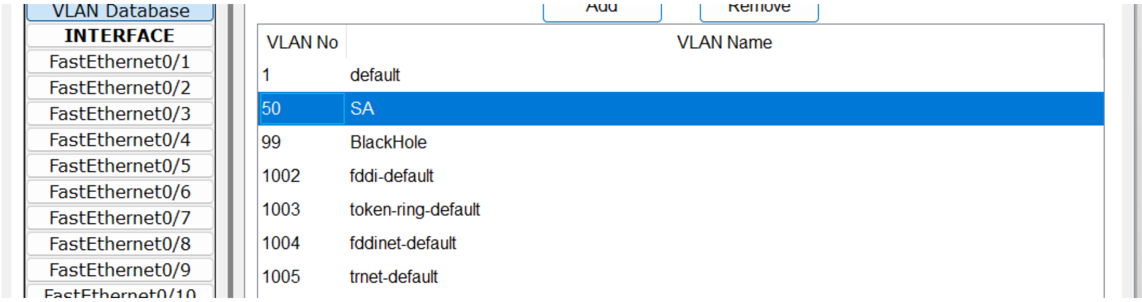
```
Students-SW(config)#
Students-SW(config)#vlan 40
Students-SW(config-vlan)# name Students
Students-SW(config-vlan)#
```

Dedicated for student devices, ensuring traffic segregation from faculty and labs.

Subnet /25 isolates student traffic and prevents broadcast domain overlap.Ensures student traffic remains separate and manageable.

- **Admin and Student Affairs:**

- VLAN 50 (Student Affairs): 172.16.3.0/25

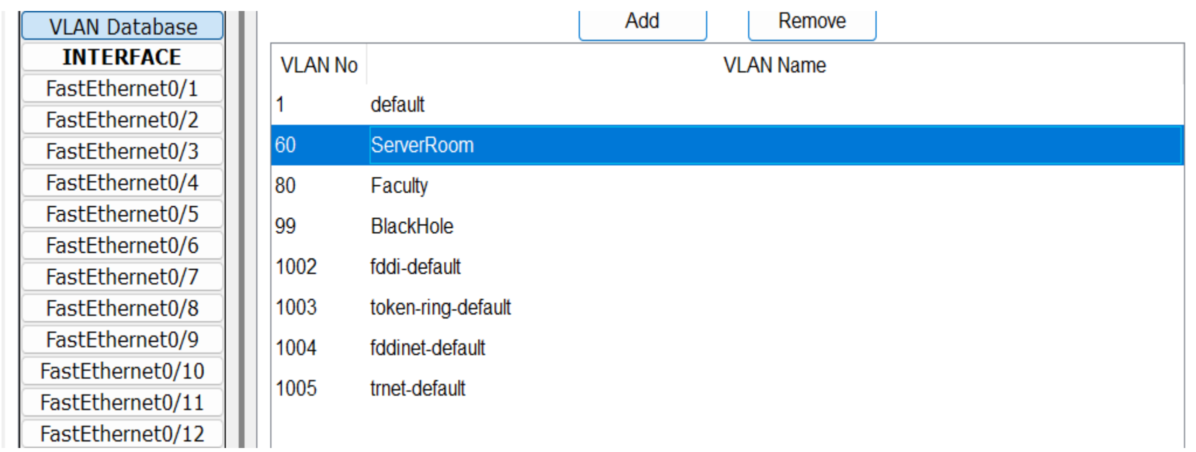


Handles administrative devices, maintaining secure and isolated operations.

Dedicated for student devices, ensuring traffic segregation from faculty and labs.

Subnet /25 isolates student traffic and prevents broadcast domain overlap.Ensures student traffic remains separate and manageable.

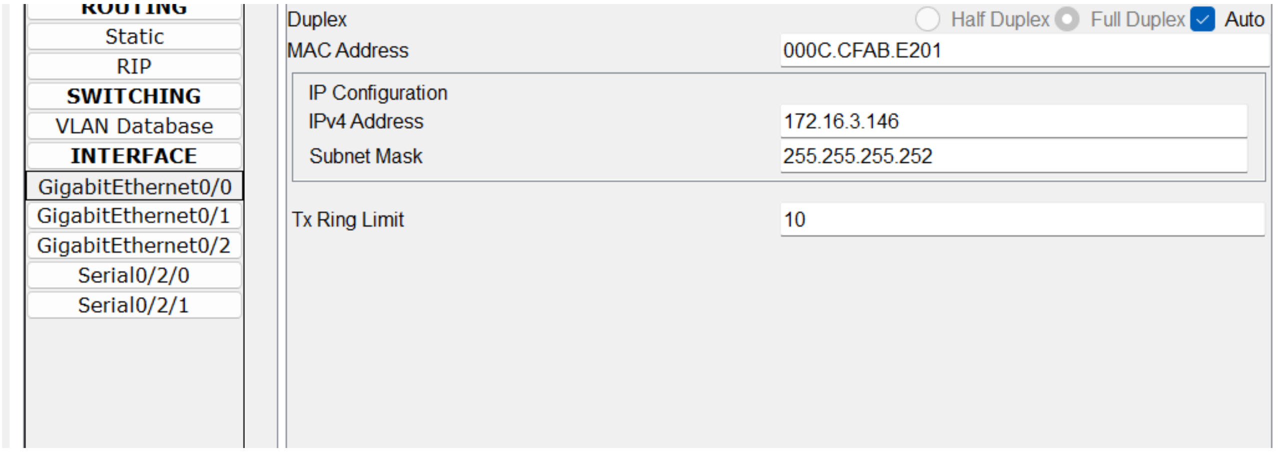
- VLAN 60 (Server Room): 172.16.3.128/25



Purpose: Dedicated for critical server infrastructure to enhance security and minimize interference.

Point-to-Point Connections:

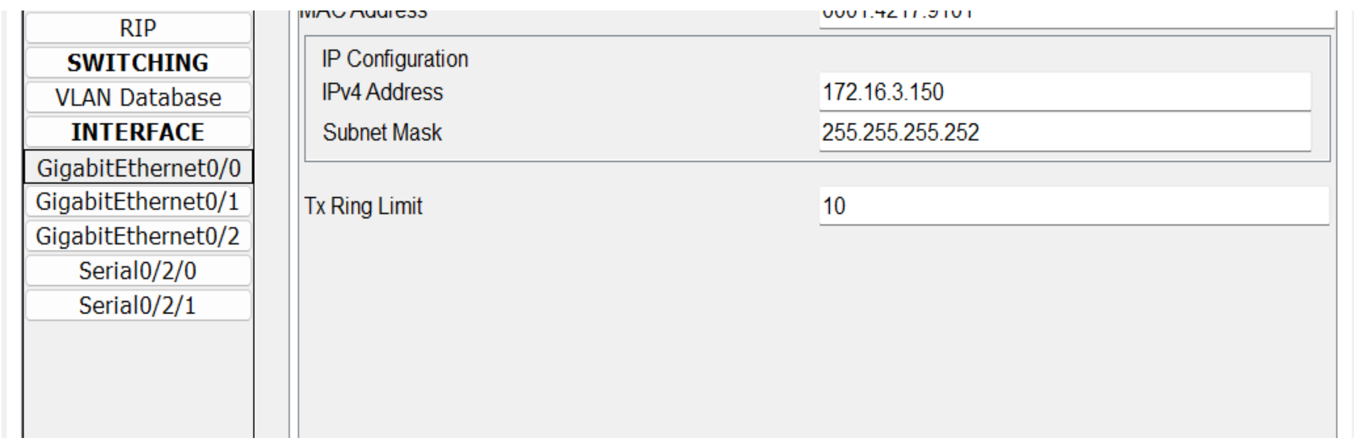
- CORE-R1 and CORE-R2:
  - 172.16.3.146/30 (GigabitEthernet0/0 on CORE-R1)



Purpose: Facilitates direct communication between core routers with minimal IP wastage.

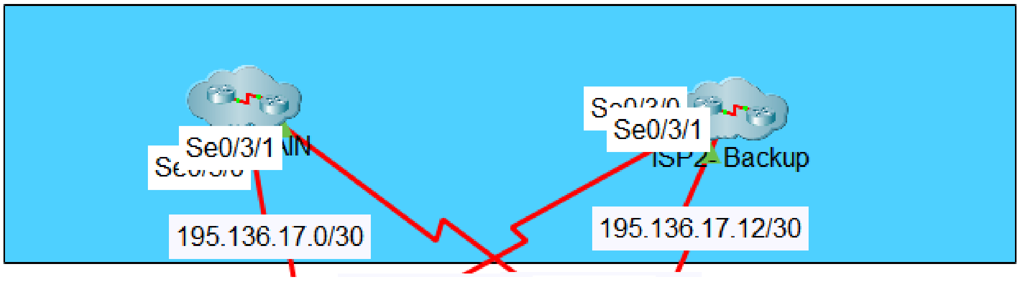
Subnet /30 provides two usable addresses, perfect for point-to-point links.

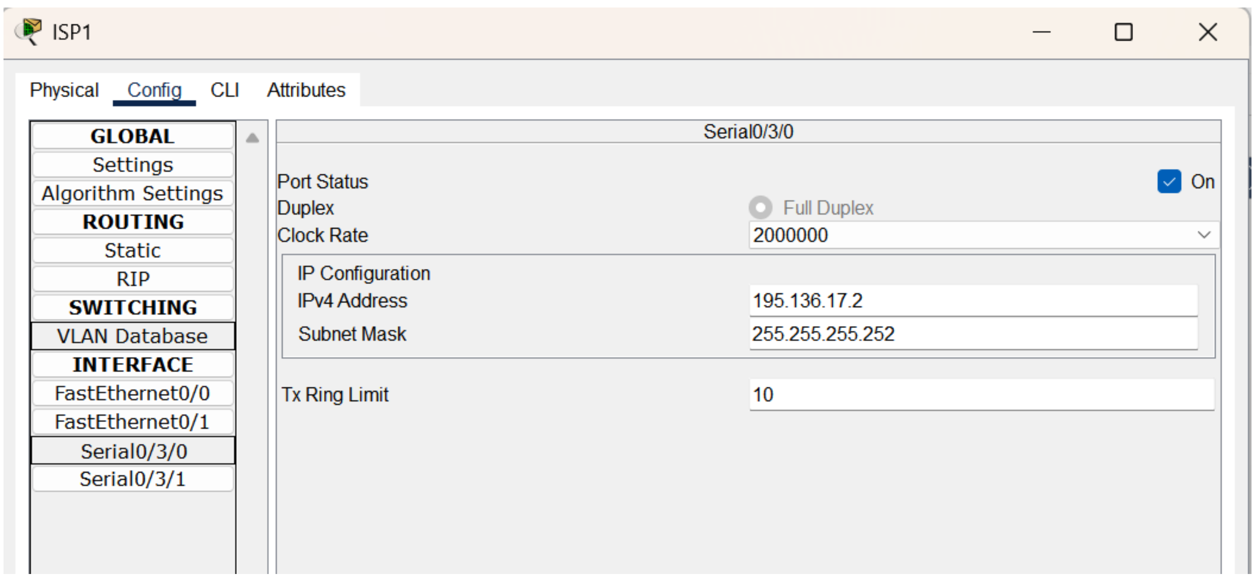
- 172.16.3.150/30 (GigabitEthernet0/0 on CORE-R2)



It Ensures redundant connections between the core routers.

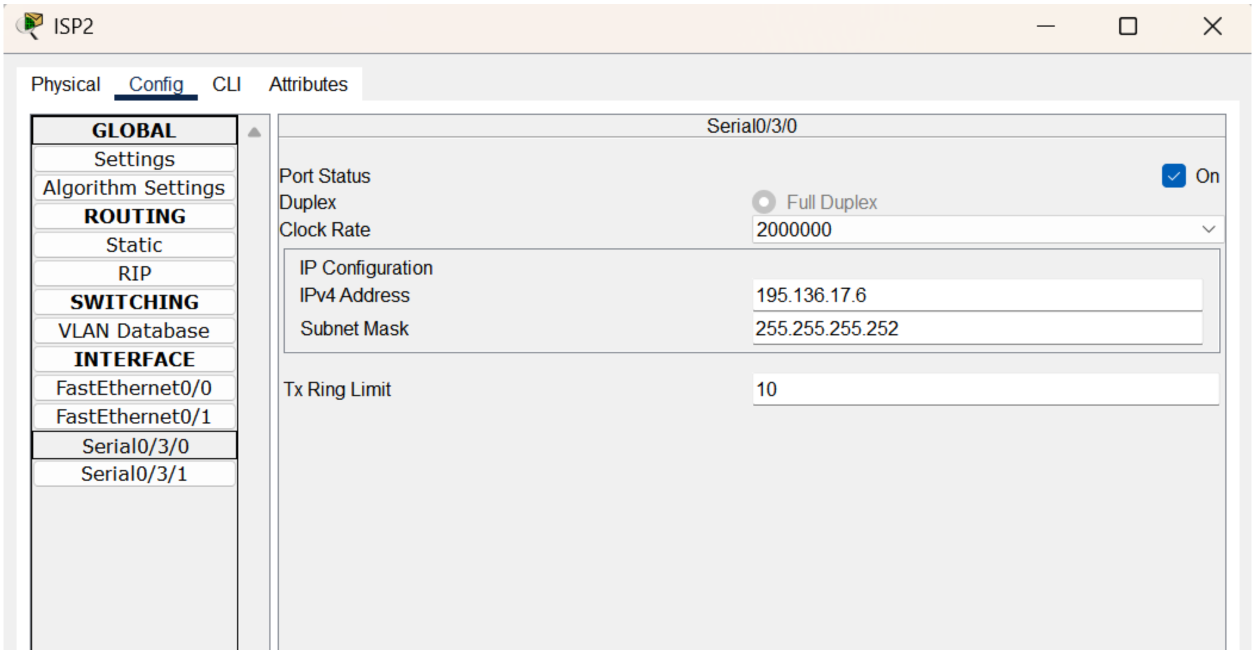
- ISP Connections:
  - Public IP range: 195.136.17.0/30





ISP 1

- Purpose: Connects the university network to ISP resources efficiently.



BACKUP ISP

STRUCTURE OF NETWORK:

- **Department of Electrical and Computer Engineering:**
  - VLAN 10 (Faculty and Labs): 172.16.1.0/25
  - VLAN 20 (Students): 172.16.1.128/25
- **Department of Social Sciences:**
  - VLAN 30 (Faculty and Labs): 172.16.2.0/25
  - VLAN 40 (Students): 172.16.2.128/25
- **Admin and Student Affairs:**
  - VLAN 50 (Student Affairs): 172.16.3.0/25
  - VLAN 60 (Server Room): 172.16.3.128/25

Point-to-Point Connections:

- CORE-R1 and CORE-R2:
  - 172.16.3.146/30 (GigabitEthernet0/0 on CORE-R1)
  - 172.16.3.150/30 (GigabitEthernet0/0 on CORE-R2)
- ISP Connections:
  - Public IP range: 195.136.17.0/30

This structured scheme ensures efficient routing, minimizes IP wastage, and provides room for future expansion.

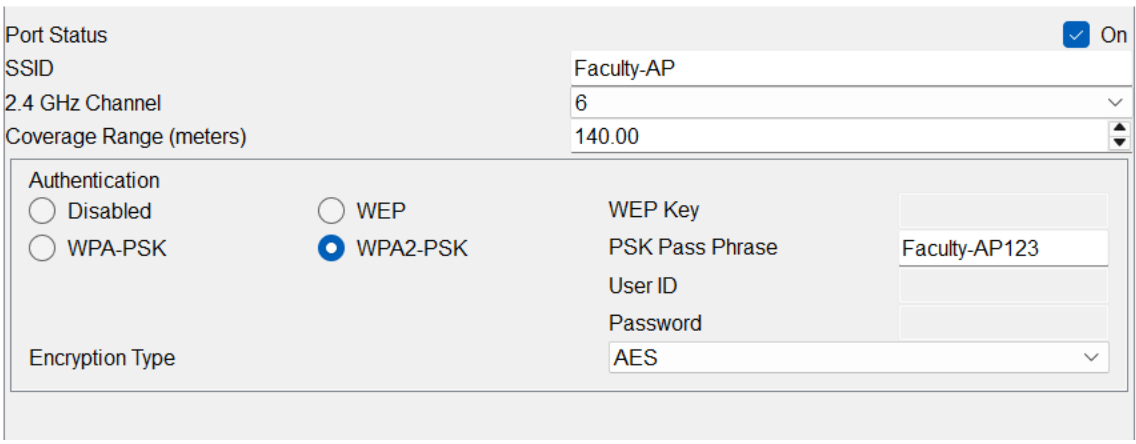
2.2 VLANs and SSIDs

VLAN Configuration:

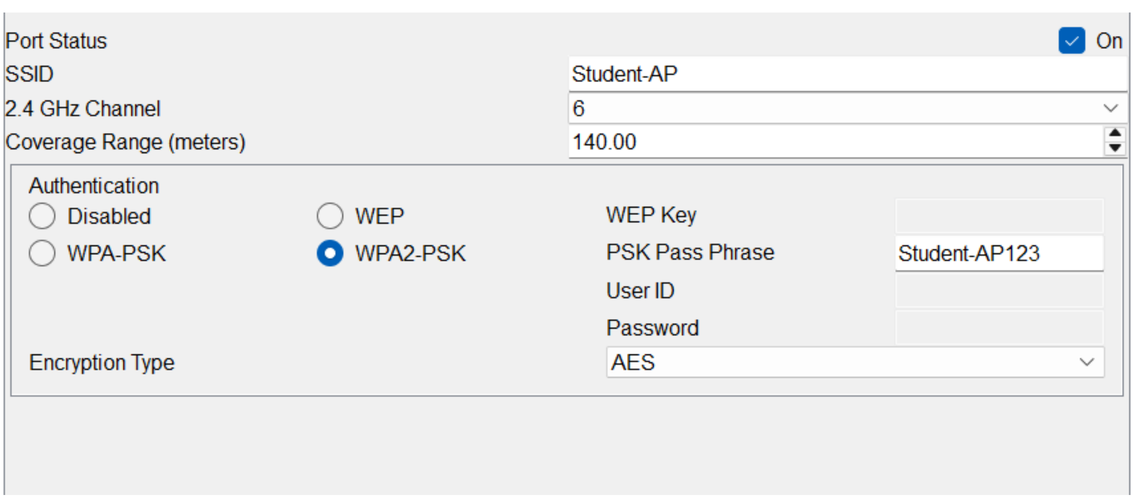
- Each department and user group is assigned a dedicated VLAN to ensure traffic segmentation and management efficiency.

Wireless Network Configuration:

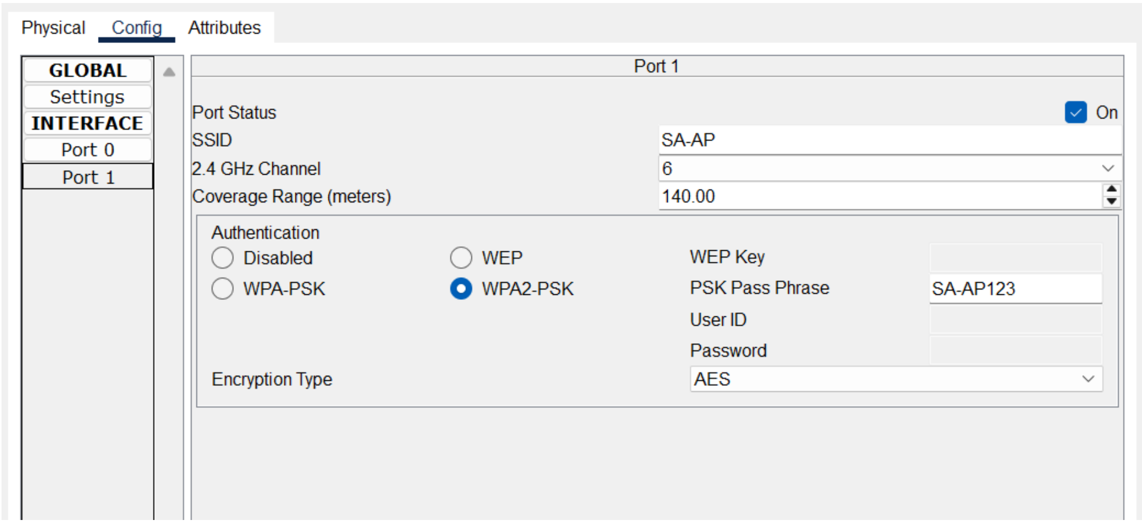
- **SSIDs and Passwords:**
  - Faculty: SSID = FACULTY; Password = Faculty-AP123



  - Students: SSID = STUDENTS; Password = Student-AP123



- Student Affairs: SSID = SA; Password = SA-AP123



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3. Router Configurations

The router configurations form the backbone of the network, ensuring connectivity, efficient routing, and high availability. Each router is meticulously configured to support the overarching network design, integrating advanced features to meet the campus's requirements.

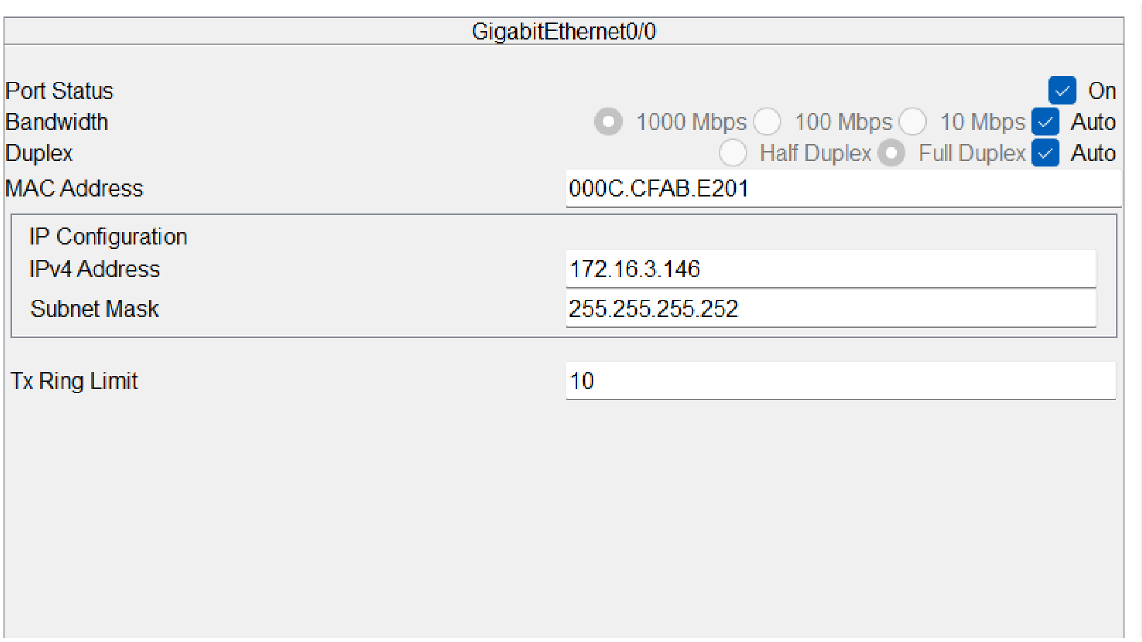
3.1 CORE-R1 Configuration

Role: CORE-R1 serves as one of the two primary routers, managing connections to internal VLANs, point-to-point links, and the ISP. It ensures data flow within the campus and provides redundancy in case of link failures.

IP Address Assignments:

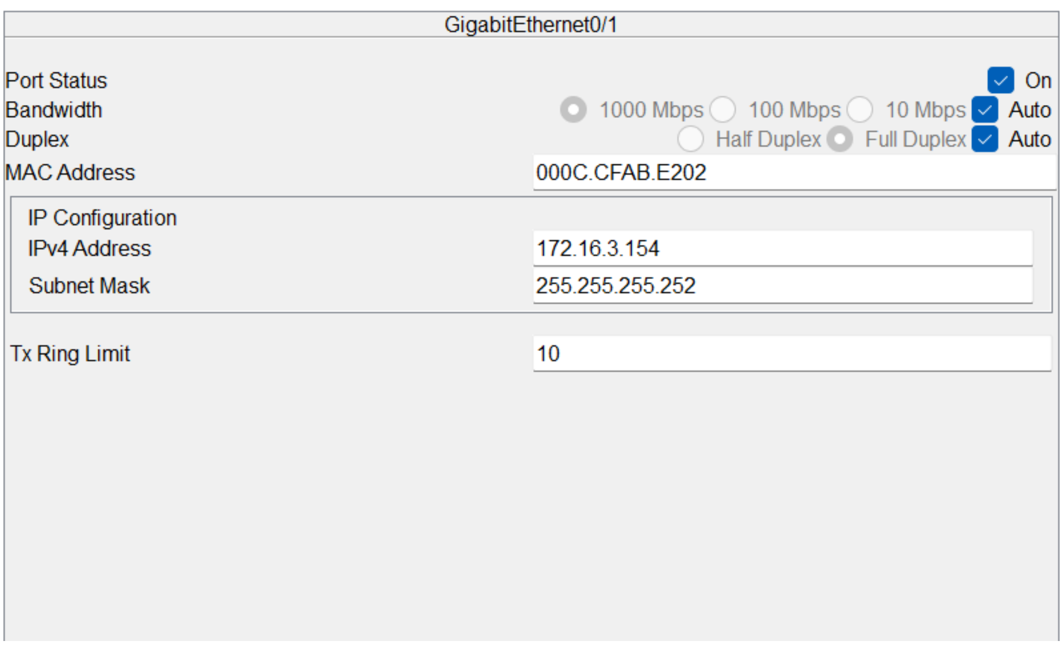
Each IP address assignment plays a critical role in ensuring seamless operation and efficient management:

- **CORE-R1:**
  - GigabitEthernet0/0: 172.16.3.146/30



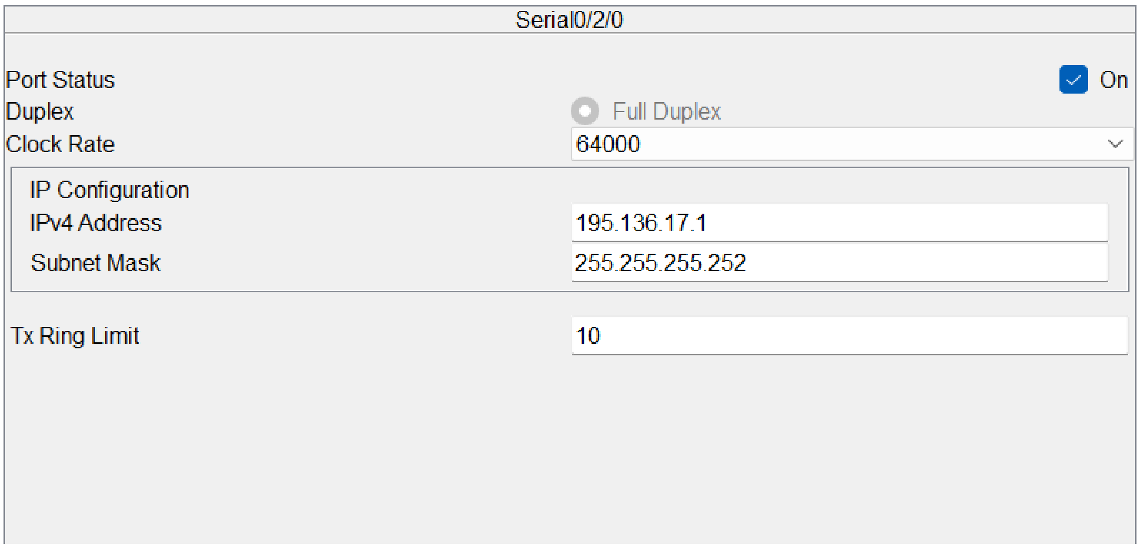
Purpose: Forms a primary link to CORE-R2, facilitating redundancy and load balancing.

  - GigabitEthernet0/1: 172.16.3.154/30



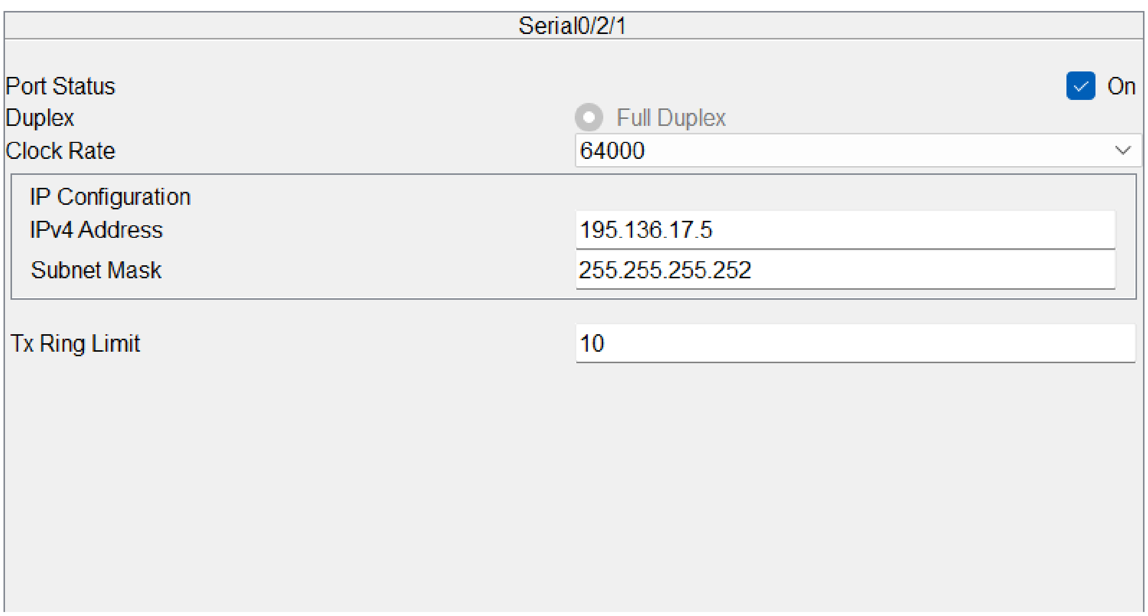
- Purpose: Interfaces with VLAN traffic, acting as a gateway for internal devices.

- Serial0/2/0: 195.136.17.1/30



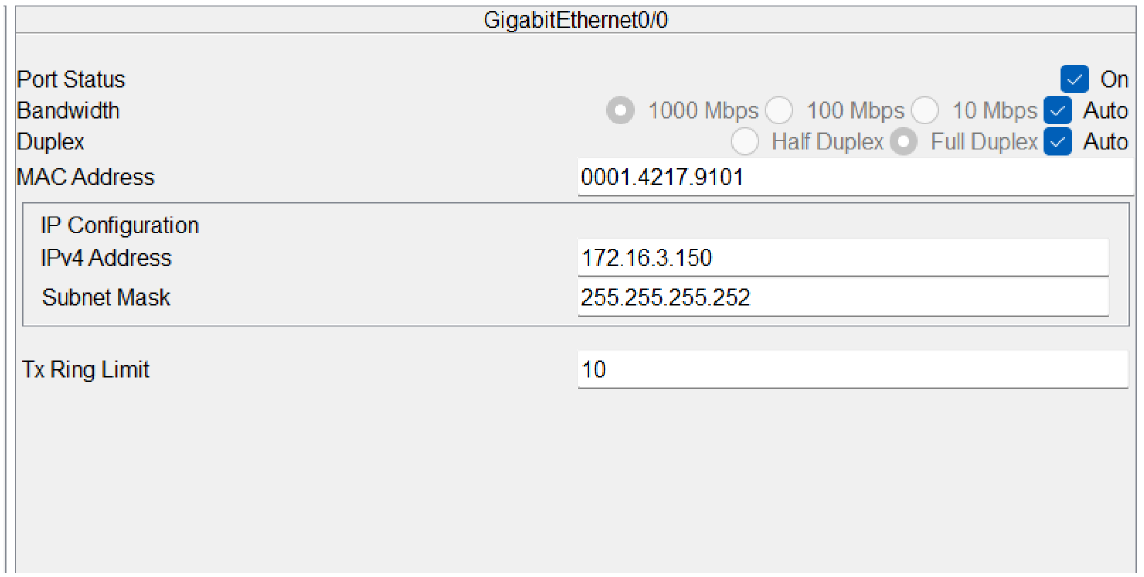
- Purpose: Provides primary connectivity to the ISP for external communications.

- Serial0/2/1: 195.136.17.5/30

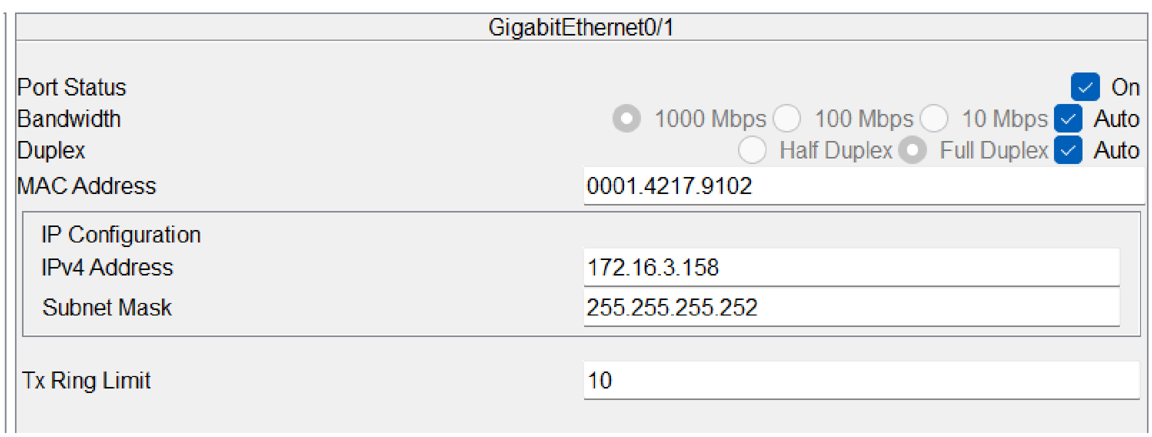


- Purpose: Serves as a backup ISP connection, enhancing fault tolerance.

- **CORE-R2:**
  - GigabitEthernet0/0: 172.16.3.150/30

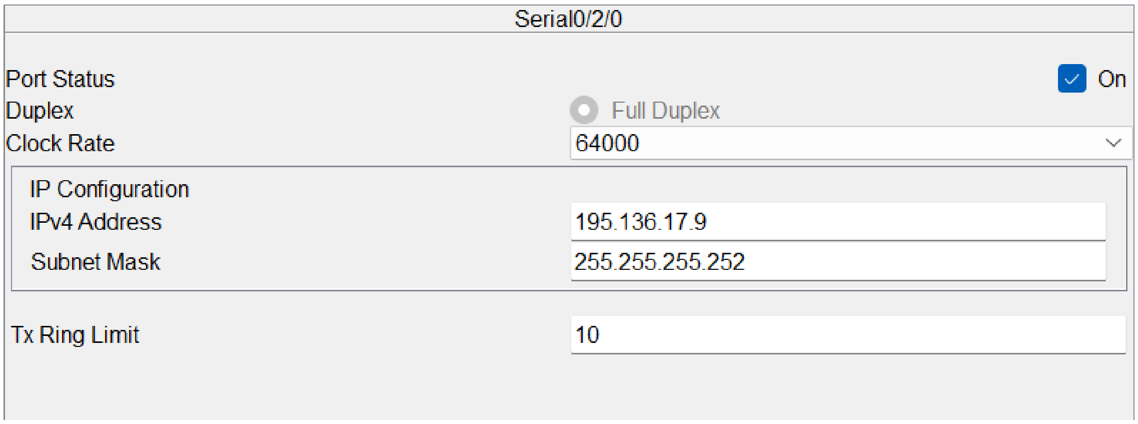


    - Purpose: Connects to CORE-R1, ensuring failover support and redundancy.
  - GigabitEthernet0/1: 172.16.3.158/30



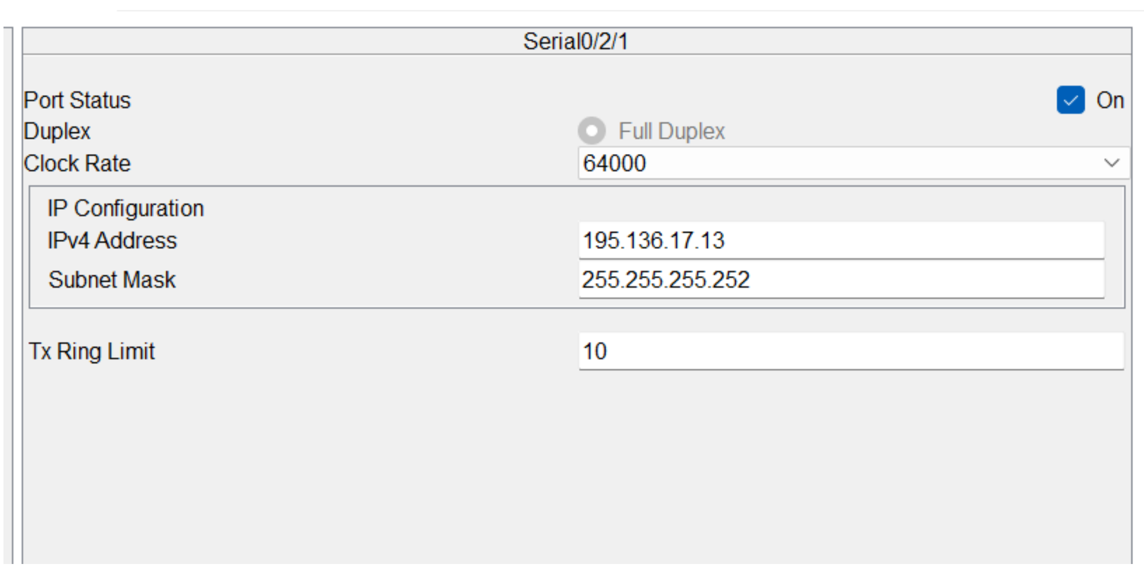
    - Purpose: Manages VLAN traffic for devices routed through CORE-R2.

- Serial0/2/0: 195.136.17.9/30



Acts as the primary ISP connection for traffic routed through CORE-R2.

- Serial0/2/1: 195.136.17.13/30



Serves as the secondary ISP connection for redundancy.

- Routing:
  - OSPF:

    1.Area 0 configured for all internal networks.

```
CORE-R2#sh ip route
Codes: L - local, C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2, E - EGP
       i - IS-IS, L1 - IS-IS level-1, L2 - IS-IS level-2, ia - IS-IS inter area
       * - candidate default, U - per-user static route, o - ODR
       P - periodic downloaded static route

Gateway of last resort is 0.0.0.0 to network 0.0.0.0

     172.16.0.0/16 is variably subnetted, 12 subnets, 4 masks
O       172.16.1.0/25 [110/2] via 172.16.3.149, 00:33:32, GigabitEthernet0/0
O       172.16.1.128/25 [110/2] via 172.16.3.149, 00:33:32, GigabitEthernet0/0
O       172.16.2.0/25 [110/2] via 172.16.3.149, 00:33:32, GigabitEthernet0/0
O       172.16.2.128/25 [110/2] via 172.16.3.149, 00:33:32, GigabitEthernet0/0
O       172.16.3.0/25 [110/2] via 172.16.3.149, 00:33:32, GigabitEthernet0/0
O       172.16.3.128/28 [110/2] via 172.16.3.149, 00:33:32, GigabitEthernet0/0
O       172.16.3.144/30 [110/2] via 172.16.3.149, 00:17:17, GigabitEthernet0/0
C       172.16.3.148/30 is directly connected, GigabitEthernet0/0
L       172.16.3.150/32 is directly connected, GigabitEthernet0/0
O       172.16.3.152/30 [110/3] via 172.16.3.149, 00:33:32, GigabitEthernet0/0
C       172.16.3.156/30 is directly connected, GigabitEthernet0/1
L       172.16.3.158/32 is directly connected, GigabitEthernet0/1
     195.136.17.0/24 is variably subnetted, 6 subnets, 2 masks
O       195.136.17.0/30 [110/66] via 172.16.3.149, 00:33:32, GigabitEthernet0/0
O       195.136.17.4/30 [110/66] via 172.16.3.149, 00:33:32, GigabitEthernet0/0
C       195.136.17.8/30 is directly connected, Serial0/2/0
L       195.136.17.9/32 is directly connected, Serial0/2/0
C       195.136.17.12/30 is directly connected, Serial0/2/1
L       195.136.17.13/32 is directly connected, Serial0/2/1
S*   0.0.0.0/0 is directly connected, Serial0/2/0
```

- RIP:
  - Enabled for legacy compatibility.
  - Static Routes:

    1.Default route via Serial0/2/0.

    2.Backup route via Serial0/2/1 with administrative distance 70.

RIP Routing

Network

Add

Network Address
172.16.0.0
195.136.17.0

- NAT:
  - Same configuration as CORE-R1.

  - Inside interfaces handle private IP traffic.
  - Outside interfaces manage internet-bound traffic.
  - Overload NAT allows multiple devices to share public IPs efficiently.

- ACLs:
  - Same ACL permitting internal VLAN traffic.

```
CORE-R2#sh access-lists
Standard IP access list 1
    10 permit 172.16.1.0 0.0.0.127
    20 permit 172.16.1.128 0.0.0.127
    30 permit 172.16.2.0 0.0.0.127
    40 permit 172.16.2.128 0.0.0.127
    50 permit 172.16.3.0 0.0.0.127
    60 permit 172.16.3.128 0.0.0.15

CORE-R2#
CORE-R2#
```

3.3 Server Configuration

Role of Servers: The network includes dedicated servers to handle critical services such as email, DHCP, and DNS. These servers are strategically located within the network to ensure optimal performance and reliability.

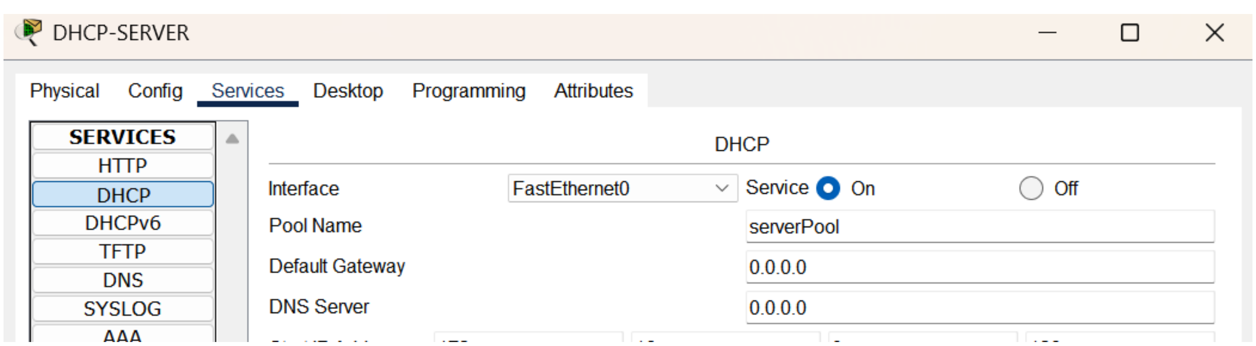
Server Details:

- **Email Server:**
  - Purpose: Provides email communication services for faculty, staff, and students.
  - Configuration: Located in VLAN 60 (Server Room) with an IP address of 172.16.3.130.
  - Functionality: Supports SMTP for sending emails, IMAP/POP3 for email retrieval, and ensures secure access with TLS encryption.

- **DHCP Server:**

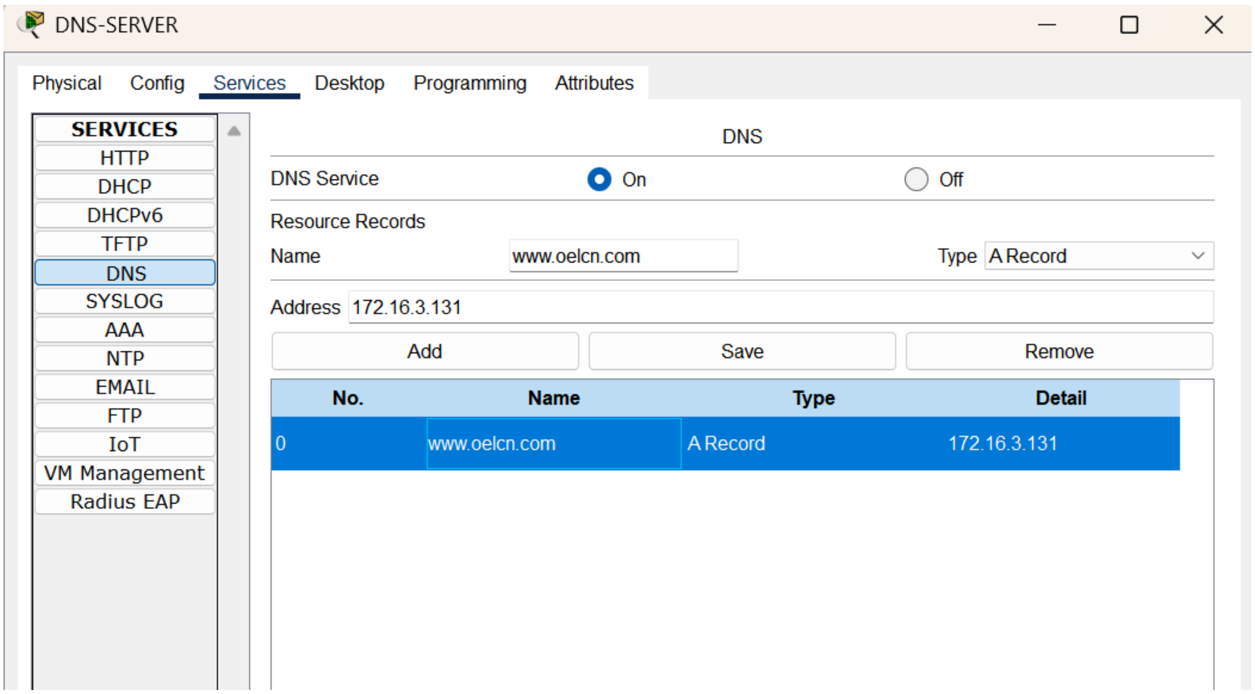
Pool Name	Default Gateway	DNS Server	Start IP Address	Subnet Mask	Max User	TFTP Server	WLC Address
Students	172.168.2....	172.16.3.131	172.16.2.134	255.255.2...	120	0.0.0.0	0.0.0.0
Students affairs	172.168.3.1	172.16.3.131	172.16.3.6	255.255.2...	120	0.0.0.0	0.0.0.0
Faculty 1	172.168.2.1	172.16.3.131	172.16.2.6	255.255.2...	120	0.0.0.0	0.0.0.0
Student iiui	172.168.1....	172.16.3.131	172.16.1.134	255.255.2...	120	0.0.0.0	0.0.0.0
DECE IIUI	172.168.1.1	172.16.3.131	172.16.1.6	255.255.2...	120	0.0.0.0	0.0.0.0
serverPool	0.0.0.0	0.0.0.0	172.16.3.128	255.255.2...	15	0.0.0.0	0.0.0.0

  - Purpose: Automates IP address allocation to devices within the network, reducing manual configuration efforts.
  - Configuration: Located in VLAN 60 (Server Room) with an IP address of 172.16.3.128

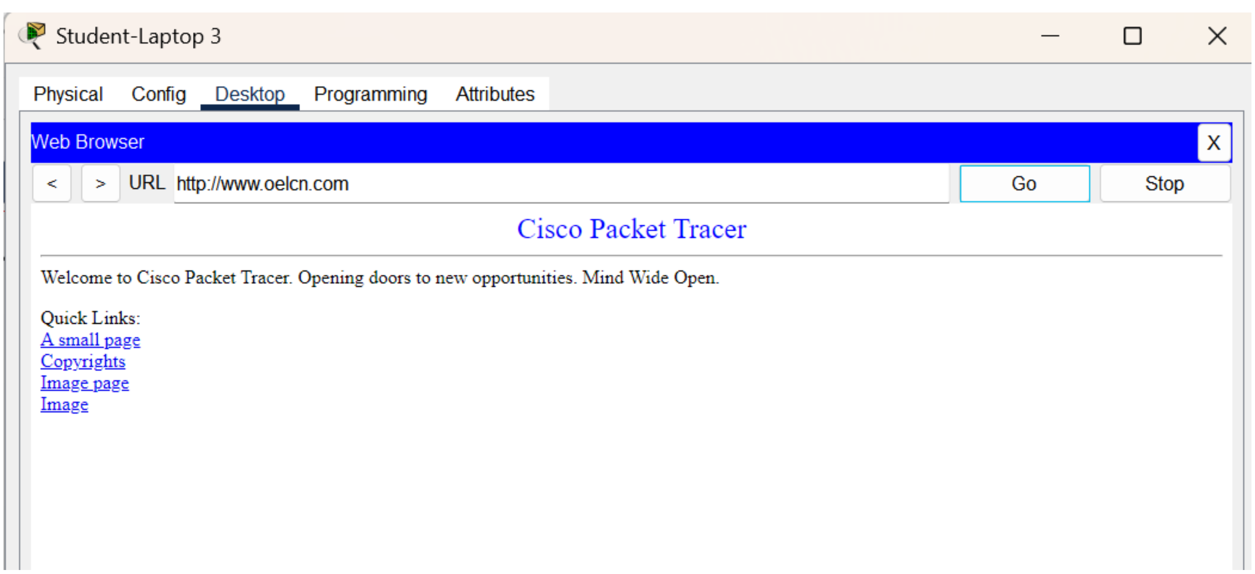


  - Functionality: Configured to dynamically assign IPs within the defined subnets (VLAN 10: 172.16.1.0/25) and lease duration policies.

- **DNS Server:**



  - Purpose: Resolves domain names to IP addresses, facilitating seamless navigation and network resource access.
  - Configuration: Located in VLAN 60 (Server Room) with an IP address of 172.16.3.132.



- Functionality: Hosts a local DNS zone for internal devices www.oelcn.com resolves to 172.16.1.10) and forwards queries for external domains to ISP DNS servers.

The router configurations form the backbone of the network, ensuring connectivity, efficient routing, and high availability. Each router is meticulously configured to support the overarching network design, integrating advanced features to meet the campus's requirements.

Throughput

The use of high-speed GigabitEthernet connections between routers and VLANs ensures that the network can handle high data transfer rates required by faculty, students, and administrative services. OSPF's efficient route calculation and load balancing further optimize the throughput by distributing traffic evenly across available paths.

Fault Tolerance

Redundant connections between CORE-R1 and CORE-R2 enhance fault tolerance. In the event of a failure in one link or router, the network automatically redirects traffic through alternate routes, minimizing downtime. Static routes with backup paths ensure uninterrupted connectivity to external networks.

Latency

By segmenting the network using VLANs, broadcast traffic is reduced, which minimizes latency. The Spanning Tree Protocol (STP) prevents loops that could lead to delays. Dynamic routing with OSPF also ensures that packets follow the most efficient paths, further reducing delays.

Scalability

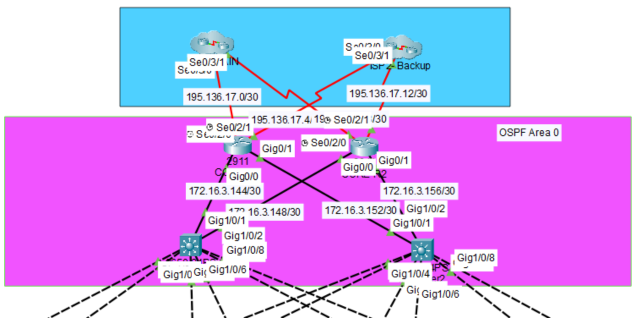
The subnetting scheme uses /25 and /30 subnets, allowing for easy addition of new VLANs or departments. Dynamic routing protocols like OSPF facilitate the seamless integration of new routers and devices without major reconfiguration.

Security

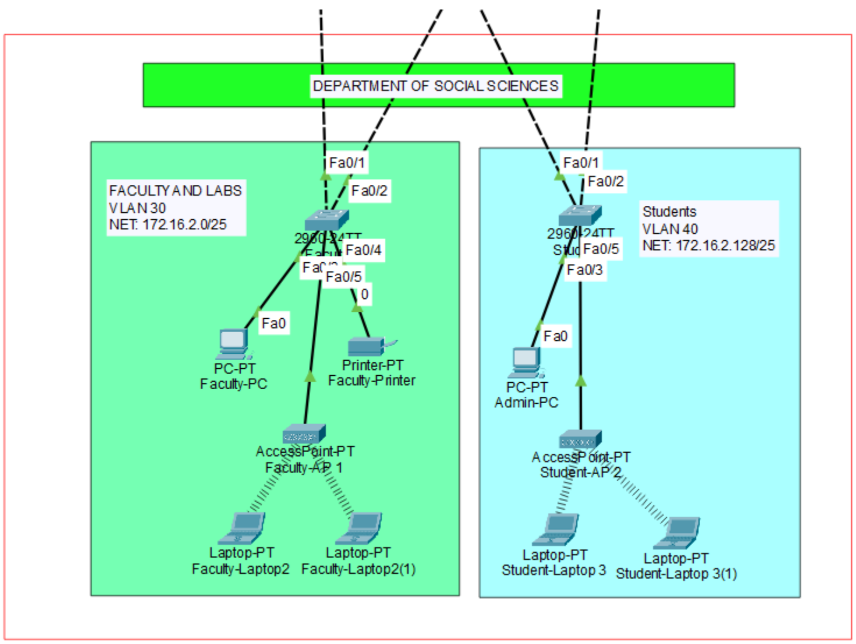
The implementation of Access Control Lists (ACLs) restricts unauthorized access, while VLAN segmentation isolates traffic between different departments and user groups. Secure Shell (SSH) access to routers ensures that network management remains protected from external threats.

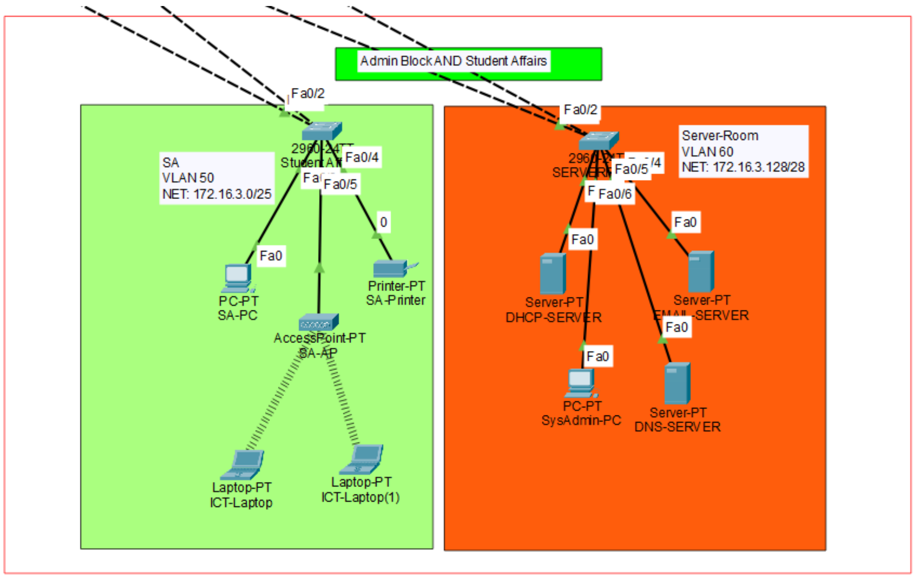
4. Main Network View:

Screenshot from packet-tracer:

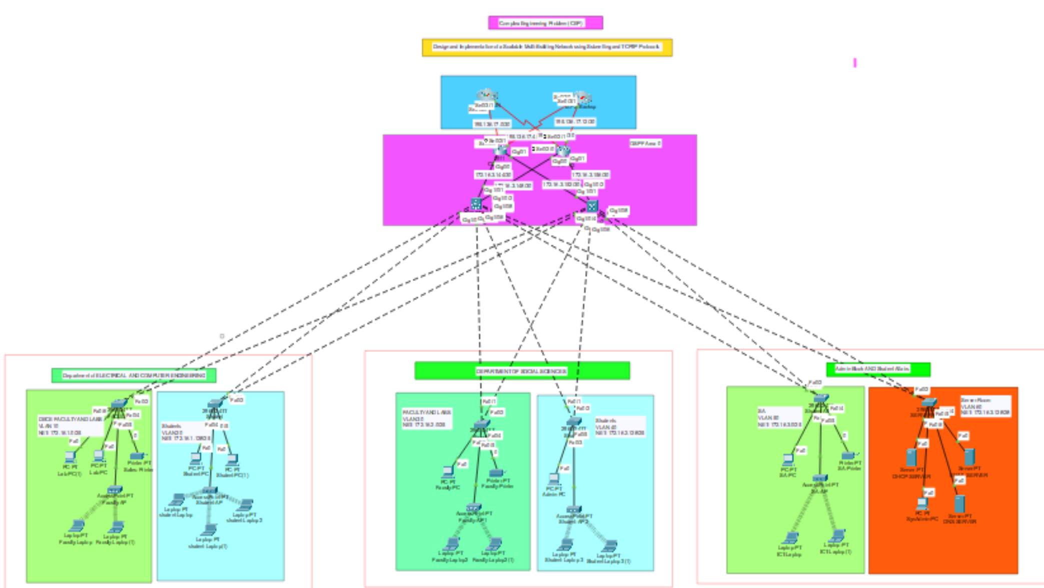


ISP 1 AND ISP BACKUP WITH CORE ROUTERS R1,R2





4.0 Complete Network View:



4.1 Structured IP Addressing Scheme

The use of /25 and /30 subnets ensures optimal utilization of IP space and allows for future scalability. Each VLAN is mapped to specific user groups or departments for efficient management and troubleshooting.

4.2 Infrastructure Setup

LAN Configuration:

- VLANs are implemented for each department and user group.
- SSIDs are configured for wireless zones, enabling controlled access.

Central Backbone:

- CORE-R1 and CORE-R2 form a resilient backbone with redundant routing paths for failover support.

4.3 Routing and Protocol Implementation

Dynamic Routing:

- OSPF is used for dynamic routing within the campus network.
- RIP provides compatibility for legacy systems.

Static Routing and NAT:

- Static routes ensure controlled traffic flow to external networks.
- NAT enables private IPs to access public resources.

4.4 Performance Optimization

Reliability:

- Redundant paths and failover mechanisms minimize downtime.
- Spanning Tree Protocol (STP) prevents network loops.

Latency:

- Efficient routing reduces latency and ensures low packet loss.

4.5 Security Measures

- SSH and password encryption safeguard router management.
- ACLs restrict unauthorized access.
- VLAN segmentation and SSIDs enhance user-group isolation.

4.6 Scalability

- Subnetting using /25 and /30 ensures room for expansion.
- Dynamic routing with OSPF allows seamless integration of new devices and networks.

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5. Conclusion

The network design aligns with the requirements of the Complex Engineering Problem (CEP) by implementing:

- Scalable and efficient IP addressing and subnetting.
- Robust routing and failover mechanisms.
- Comprehensive security measures.

This project has significantly enhanced the university's network infrastructure by ensuring reliable and secure connectivity across all departments. The use of dynamic routing protocols like OSPF and VLAN segmentation has optimized network performance and management efficiency. Moreover, the network's architecture supports seamless integration of future technologies, such as IPv6 transition, advanced wireless solutions, and cloud-based services. With its scalable design, the network is well-prepared to accommodate growing demands, new buildings, and additional user groups, ensuring long-term sustainability and adaptability.

The network design aligns with the requirements of the Complex Engineering Problem (CEP) by implementing:

- Scalable and efficient IP addressing and subnetting.
- Robust routing and failover mechanisms.
- Comprehensive security measures.

This project demonstrates a balance between advanced technical solutions and practical implementation, ensuring the network meets both current and future demands.

Acknowledgments

I extend my heartfelt gratitude to Dr. Zahoor-ud-din Sheikh for his invaluable guidance, support, and insights, which were instrumental in the successful completion of this project.