ENCS4130
Computer Networks Laboratory

EXP#4 Dynamic Routing 2 (Link State Routing Protocols) Open Shortest Path First (OSPF)

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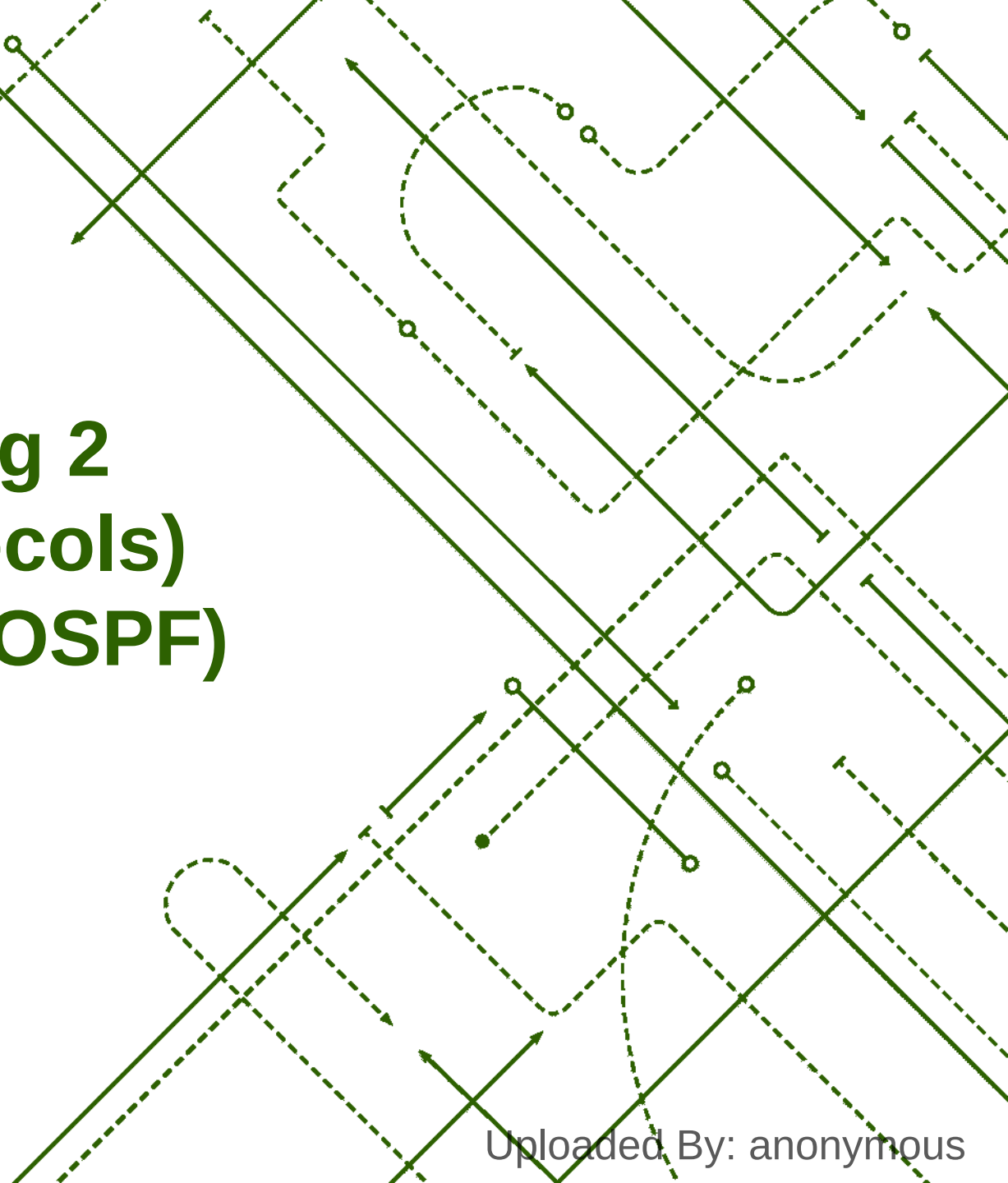

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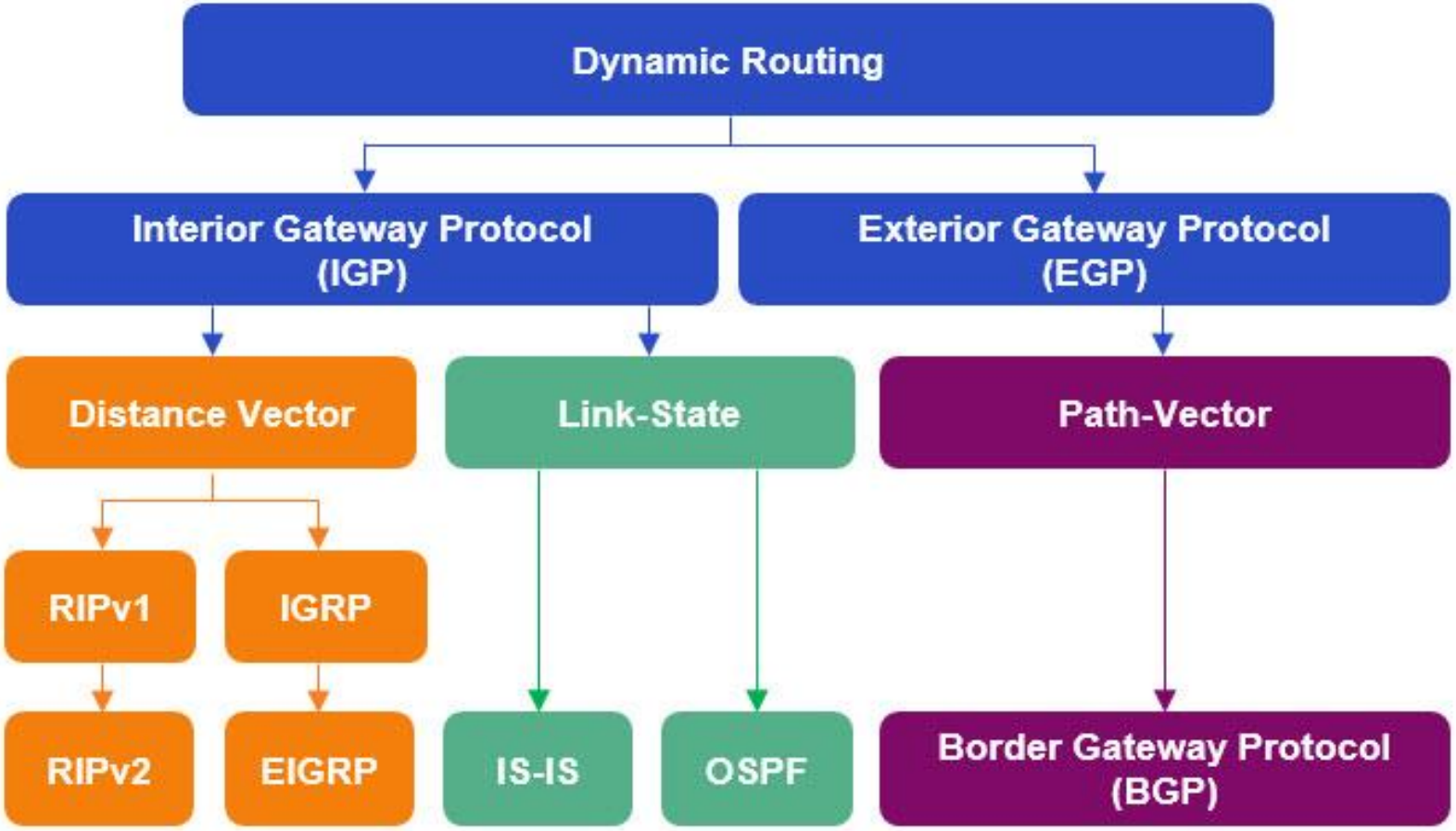
Objectives

- Learn how to configure and verify IP routing with Cisco routers.
- Basic OSPF Configuration and OSPF Adjacencies.
- How OSPF Builds the Routing Table.

Introduction



Introduction (Cont.)

- **Interior Gateway Protocol (IGP):**
  - Designed for IP networks.
  - Supports Variable Length Subnet Masks (VLSM), making it a classless routing protocol.
- **Link-State Routing Protocol:**
  - Uses Link-State Advertisements (LSAs) instead of full routing table updates.
  - Faster network convergence compared to distance-vector protocols.
- **Shortest Path First (SPF) Algorithm:**
  - OSPF calculates the shortest path to all known destinations using the Dijkstra Algorithm.

OSPF Features & Usage

- **Multivendor Support:**
  - Compatible with routers from different vendors (not just Cisco).
  - Ideal for multi-vendor environments.
- **Packet Authentication:**
  - OSPF can authenticate packets exchanged between routers.
- **Multicast Communication:**
  - Uses IP multicast to efficiently send and receive routing information.
- **OSPF is the protocol of choice when:**
  - The network includes routers from multiple vendors.
  - The network needs to be segmented into areas or zones.

OSPF Operation Overview

1. **Establish Neighbour Adjacencies**
   - OSPF routers send Hello packets to find and form adjacencies with neighbours.
2. **Exchange Link-State Advertisements (LSAs)**
   - Routers share LSAs with neighbours to update the state and cost of links.
3. **Build the Topology Table (LSDB)**
   - Routers compile received LSAs to build a complete network topology database.
4. **Execute the SPF Algorithm**
   - Routers run the SPF (Dijkstra) algorithm to create the shortest path tree.
5. **Build the Routing Table**
   - The best paths from the SPF tree are added to the routing table for decision-making.

OSPF Neighbour Relationships

- **OSPF Neighbour Relationships:**
  - Hello messages are sent every 10 seconds on broadcast/point-to-point networks.
- **Key Information in Hello Messages:**

Router ID	**Hello and dead timers**	**Network mask**
Area id	Neighbours	Router priority
DR/BDR IP addresses		Authentication password

- **Matching Parameters for Neighbour Relationship:**
  - Bolded parameters (Area ID, Hello and dead timers) must match between routers to establish an OSPF neighbour relationship**.**

OSPF Metric

- **Cost Metric Formula:**

$$\text{Cost} = \frac{\text{Reference Bandwidth}}{\text{Interface Bandwidth}}$$

- **Default reference bandwidth: 100 Mbps**

- **Example:**
  - 100 Mbps link: Cost = 1
  - 10 Mbps link: Cost = 10
  - 1 Gbps (or faster) link: Cost = 1 (minimum cost is 1)

Media type	Default bandwidth	Default OSPF cost
Ethernet	10 Mbps	10
Fast Ethernet	100 Mbps	1
FDDI	100 Mbps	1
T-1 (serial interface)	1,544 kbps	64

OSPF vs (RIP & EIGRP)

- **OSPF (Link-State Protocol):**
  - Link-State Advertisements (LSAs):
  - Sent to all routers within the same area.
  - Each router builds and maintains an identical Link-State Database.
  - Faster convergence due to efficient updates.
  - Classless Routing
- **RIP & EIGRP (Distance-Vector Protocol):**
  - Routing Table Updates:
  - Sent only to directly connected neighbours.
  - Neighbours then propagate the routing table updates to their own neighbours.
  - Results in slower convergence as updates travel hop-by-hop through the network.
  - Classful Routing

Routing Hierarchy

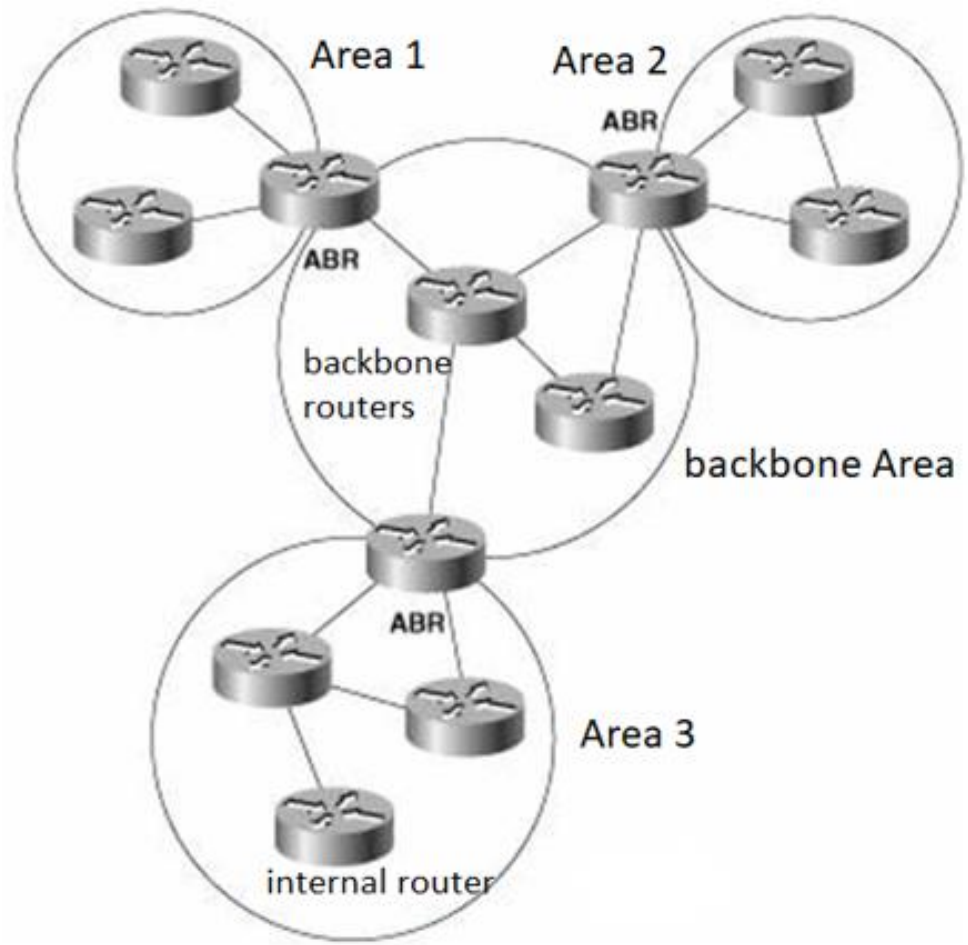
- **Autonomous System (AS):**
  - A collection of networks under a common administration sharing a common routing strategy.
  - OSPF is an intra-AS routing protocol, meaning it operates within an AS, although it can exchange routes with other ASes.
- **Areas:**
  - An AS can be divided into multiple areas, which are groups of contiguous networks and attached hosts.
  - Each area has its own topology that is invisible to routers outside that area, reducing routing traffic across the network.

Area Border Routers (ABRs) & OSPF Backbone

- **Area Border Routers (ABRs):**
  - Routers with multiple interfaces that participate in multiple areas.
  - They maintain separate topological databases for each area they connect.

- **Backbone Area (Area 0):**
  - Responsible for distributing routing information between areas.
  - All areas must connect to the backbone area (directly or through a virtual link).
  - **intra-area routing** is like "pinging" or communicating within the same area.
  - **inter-area routing** is like "pinging" or communicating across different areas.

Area Border Routers (ABRs) & OSPF Backbone (Cont.)



Route Summarization

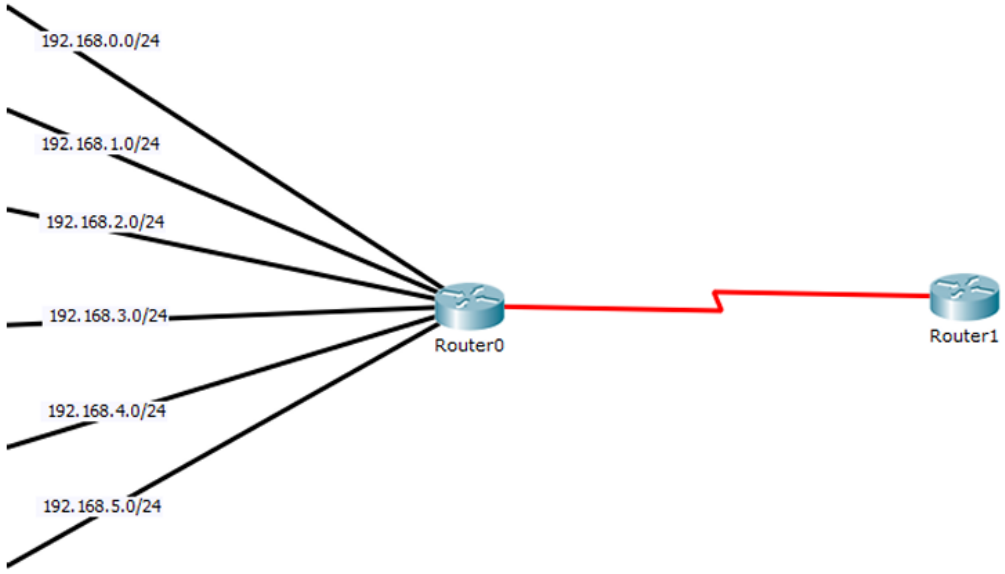
- **Definition:** The process of replacing a series of specific routes with a single summary route and subnet mask.
- **Benefits:**
  - Smaller routing tables: Reduces the number of routes in the routing table.
  - Efficient updates: Decreases the size of routing update packets.
  - Complete IP connectivity: When done correctly, IP connectivity remains intact.

OSPF Route Summarization Command:

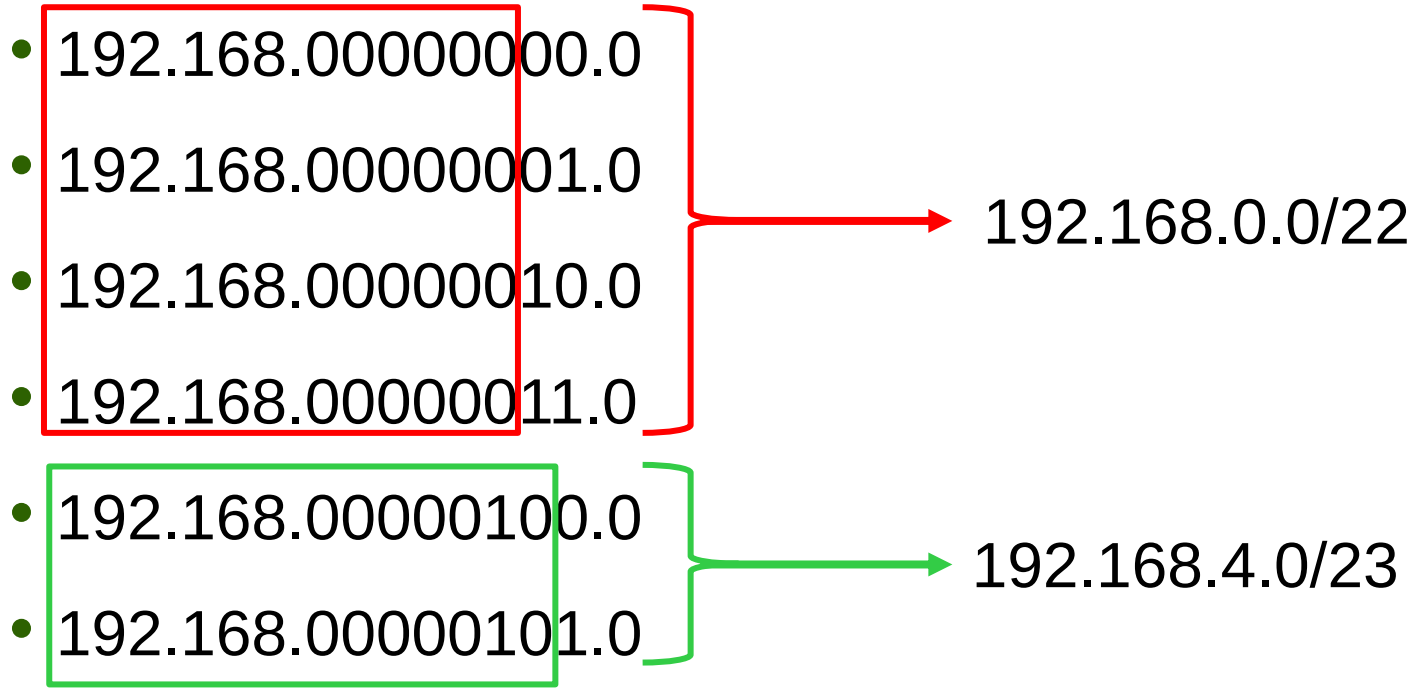
- **To summarize routes between areas:**
  - Router(config-router)# area AREA-ID range <SUMMARY-ADDRESS> <SUBNET-MASK>

Route Summarization Example

- **Router 0 has 6 specific routes:**
  - 192.168.0.0/24, 192.168.1.0/24, …, 192.168.5.0/24.
- **These routes can be summarized into two:**
  - 192.168.0.0/22
  - 192.168.4.0/23
- **Why Not Use a Single Summary Route?**
  - We cannot summarize using 192.168.0.0/21 because it would include networks (e.g., 192.168.6.0/24 and 192.168.7.0/24) that are not connected to Router 1.



Route Summarization Example (Cont.)



Enabling and Configuring OSPF

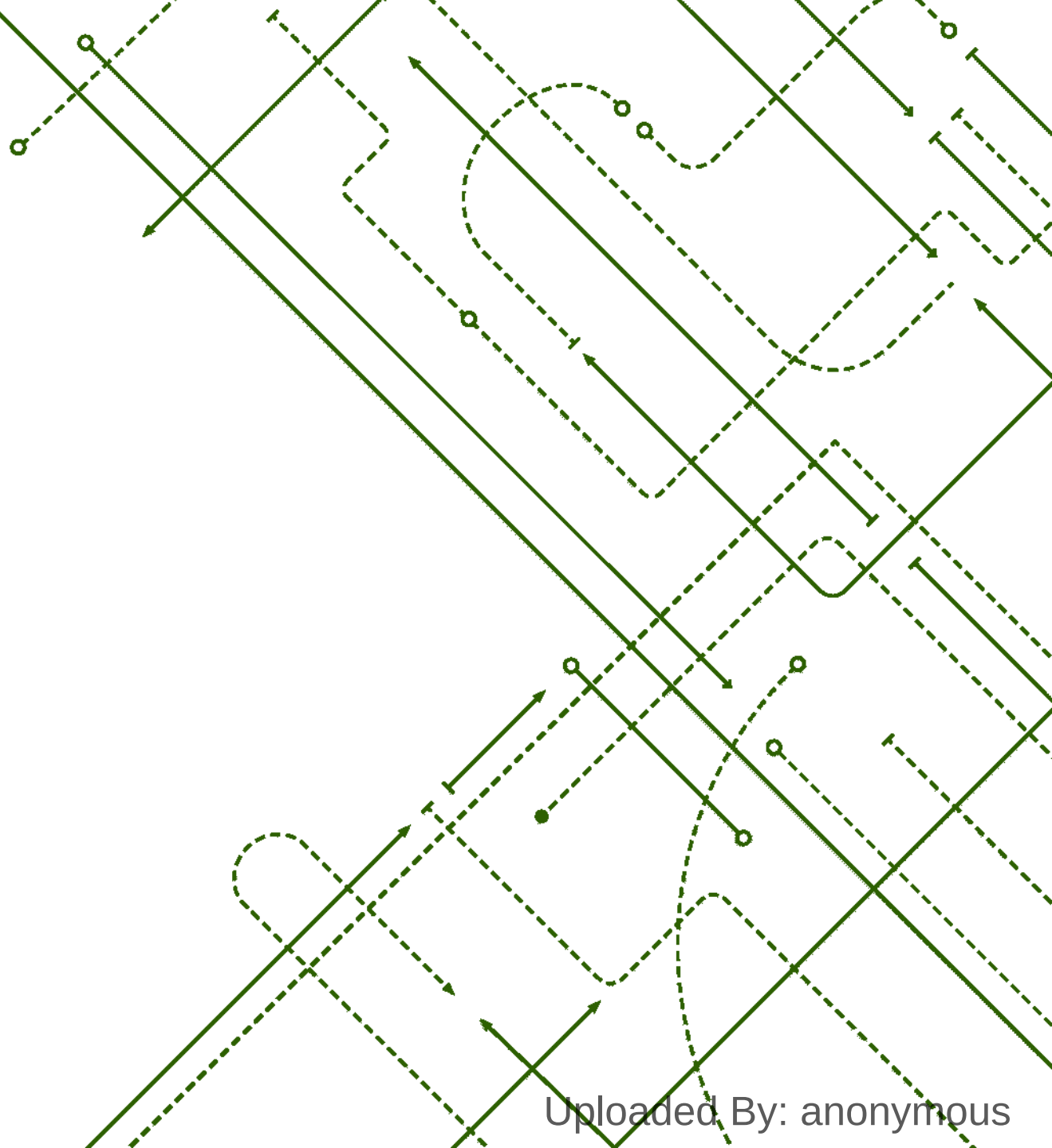
- **Steps to Enable OSPF:**
  - **Start OSPF process:**
    - **Router(config)# router ospf <PROCESS-ID>**
  - **Add networks to OSPF:**
    - **Router(config-router)# network <ID-ADDRESS> <WILDCARD-MASK> area <AREA-ID>**

- **Commands to Check OSPF Status:**
  - **Router# show ip route**
  - **Router# show ip ospf neighbor**
  - **Router# show ip protocols**

Enabling and Configuring OSPF (Cont.)

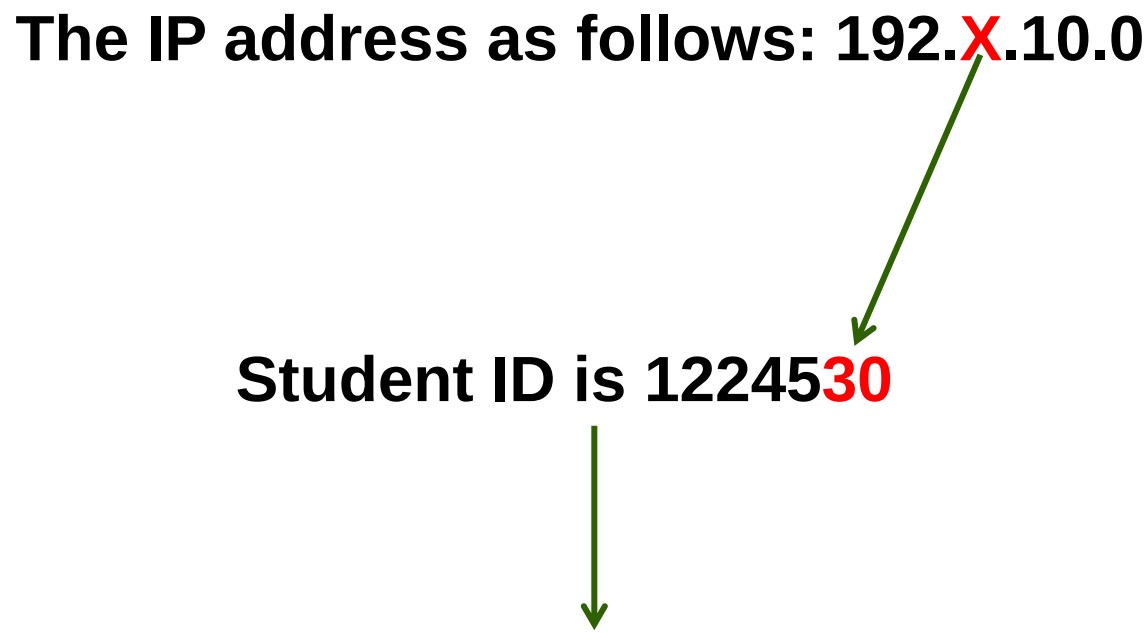
- **Router ID:**
  - Identifies the router to OSPF neighbours.
  - Default: Highest physical interface IP at startup (loopback interfaces take precedence).
  - To manually configure the Router ID:
    - **Router(config-router)# router-id <A.B.C.D>**

Procedure



IP Address

- The IP address as follows: 192.X.10.0 → where X is : for example, student ID is 1224530, X = 30, and so the network will be 192.30.10.0/S.M



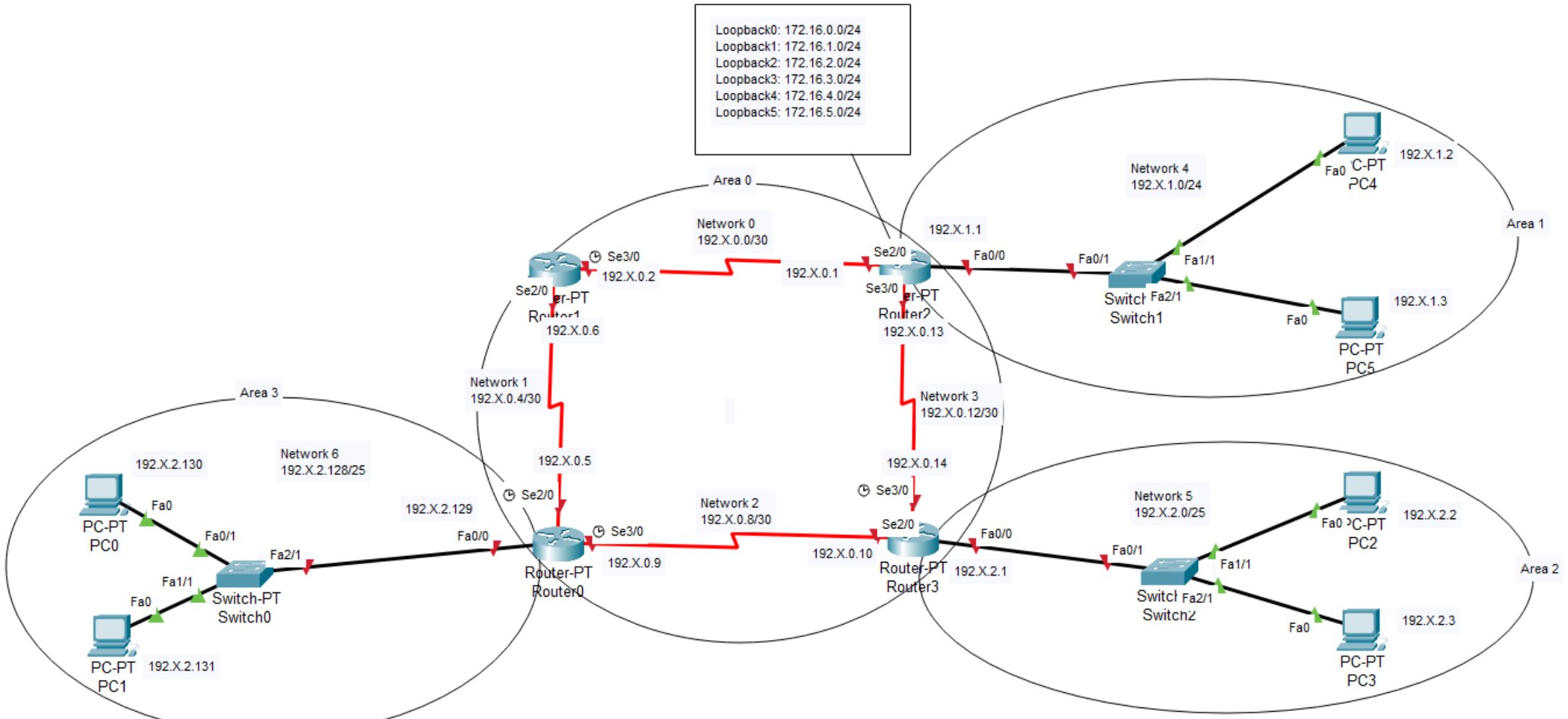
Topology

- **The topology contains:**

Name	Quantity	Symbol
Router-PT	4	 Router-PT
Switch-PT	3	 Switch-PT
PC-PT	6	 PC-PT

- Use Automatically use connection type: 

Topology (Cont.)



Networks IPS – Area 0

Area	Network	Device	Interface	IP	Subnet Mask	Wildcard Mask
Area 0	Network 0 192.X.0.0/30	Router 2	Se2/0	192.X.0.1	255.255.255.252	0.0.0.3
		Router 1	Se3/0	192.X.0.2	255.255.255.252	0.0.0.3
	Network 1 192.X.0.4/30	Router 0	Se2/0	192.X.0.5	255.255.255.252	0.0.0.3
		Router 1	Se2/0	192.X.0.6	255.255.255.252	0.0.0.3
	Network 2 192.X.0.8/30	Router 0	Se3/0	192.X.0.9	255.255.255.252	0.0.0.3
		Router 3	Se3/0	192.X.0.10	255.255.255.252	0.0.0.3
	Network 3 192.X.0.12/30	Router 2	Se3/0	192.X.0.13	255.255.255.252	0.0.0.3
		Router 3	Se2/0	192.X.0.14	255.255.255.252	0.0.0.3

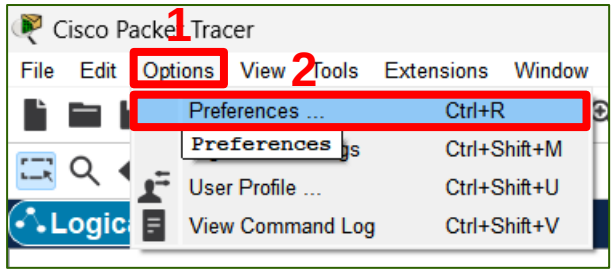
Networks IPS – Area 1,2 and 3

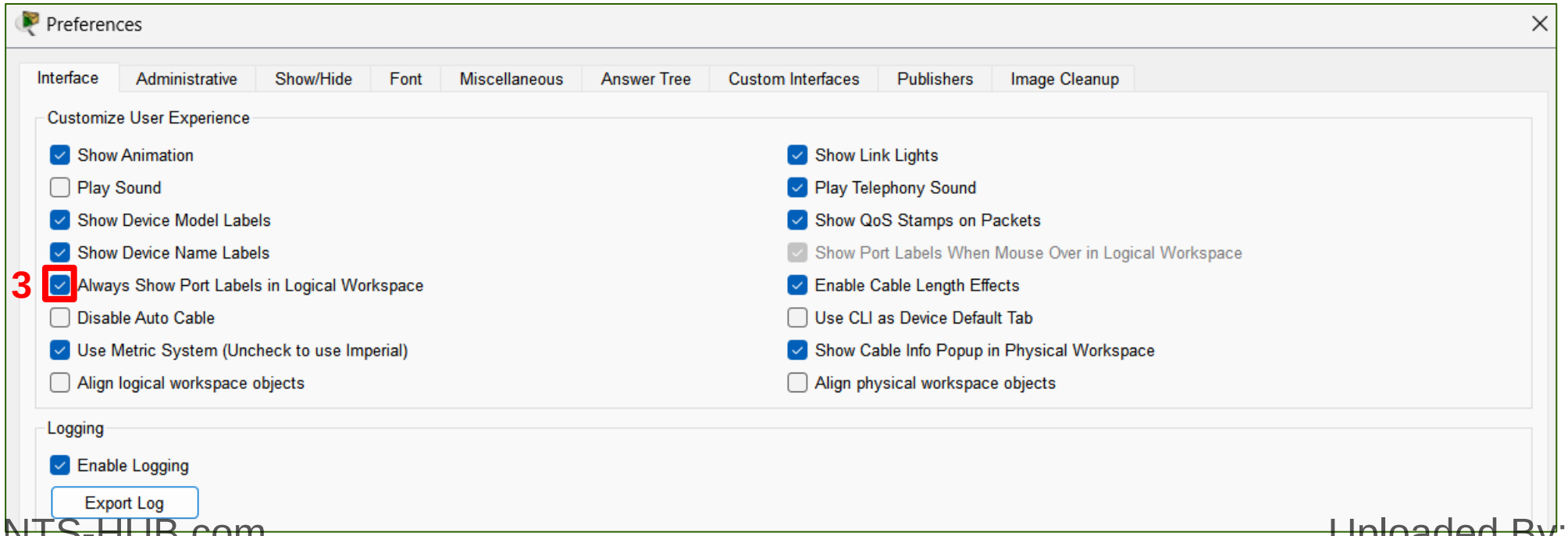
Area	Network	Device	Interface	IP	Subnet Mask	Wildcard Mask
Area 1	Network 4 192.X.1.0/24	Router 2	Fa0/0	192.X.1.1	255.255.255.0	0.0.0.255
		PC4	Fa0	192.X.1.2	255.255.255.0	0.0.0.255
		PC5	Fa0	192.X.1.3	255.255.255.0	0.0.0.255
Area 2	Network 5 192.X.2.0/25	Router 3	Fa0/0	192.X.2.1	255.255.255.128	0.0.0.127
		PC2	Fa0	192.X.2.2	255.255.255.128	0.0.0.127
		PC3	Fa0	192.X.2.3	255.255.255.128	0.0.0.127
Area 3	Network 6 192.X.2.128/25	Router 0	Fa0/0	192.X.2.129	255.255.255.128	0.0.0.127
		PC0	Fa0	192.X.2.130	255.255.255.128	0.0.0.127
		PC1	Fa0	192.X.2.131	255.255.255.128	0.0.0.127

Networks IPS – Summarization

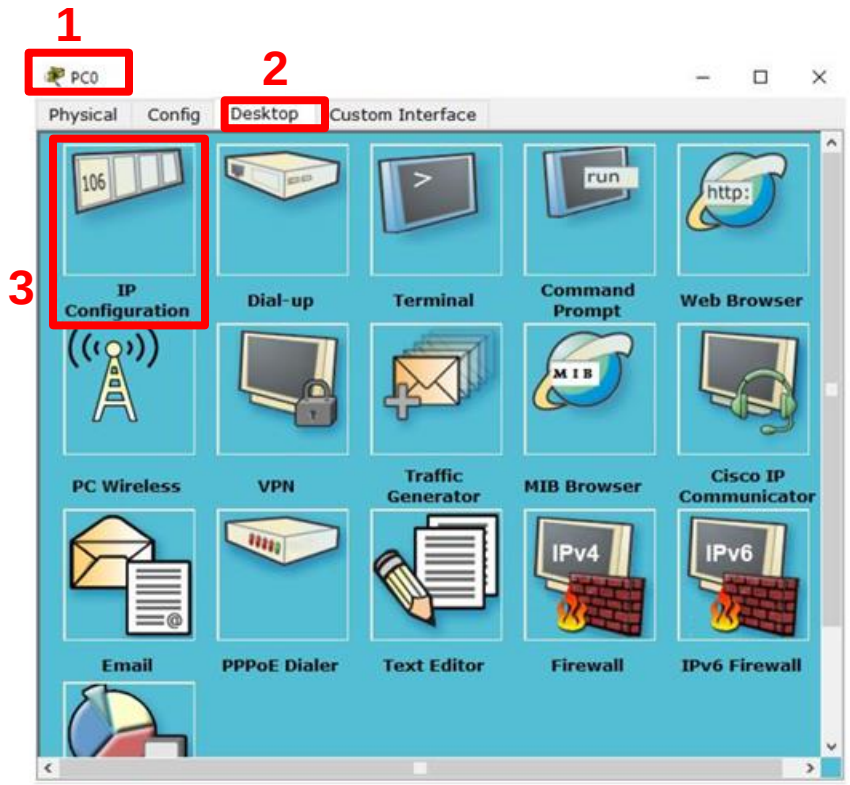
Summarization	Network	Device	Interface	IP	Subnet Mask	Wildcard Mask
Summarization 172.16.0.0/22	172.16.0.0/24	Router 2	Loopback0	172.16.0.1	255.255.255.0	0.0.0.255
	172.16.1.0/24	Router 2	Loopback1	172.16.1.1	255.255.255.0	0.0.0.255
	172.16.2.0/24	Router 2	Loopback2	172.16.2.1	255.255.255.0	0.0.0.255
	172.16.3.0/24	Router 2	Loopback3	172.16.3.1	255.255.255.0	0.0.0.255
Summarization 172.16.4.0/23	172.16.4.0/24	Router 2	Loopback4	172.16.4.1	255.255.255.0	0.0.0.255
	172.16.5.0/24	Router 2	Loopback5	172.16.5.1	255.255.255.0	0.0.0.255

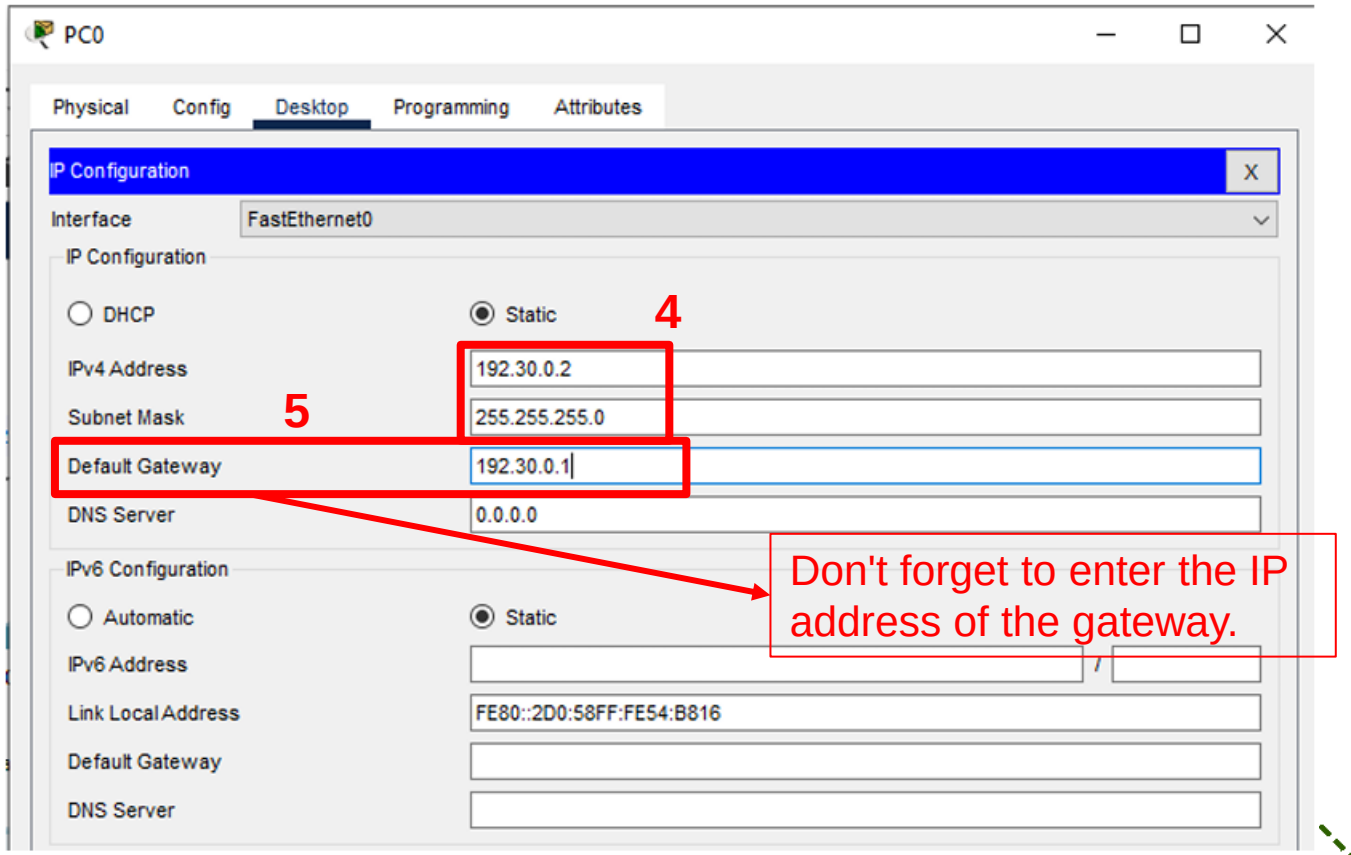
Show the port labels





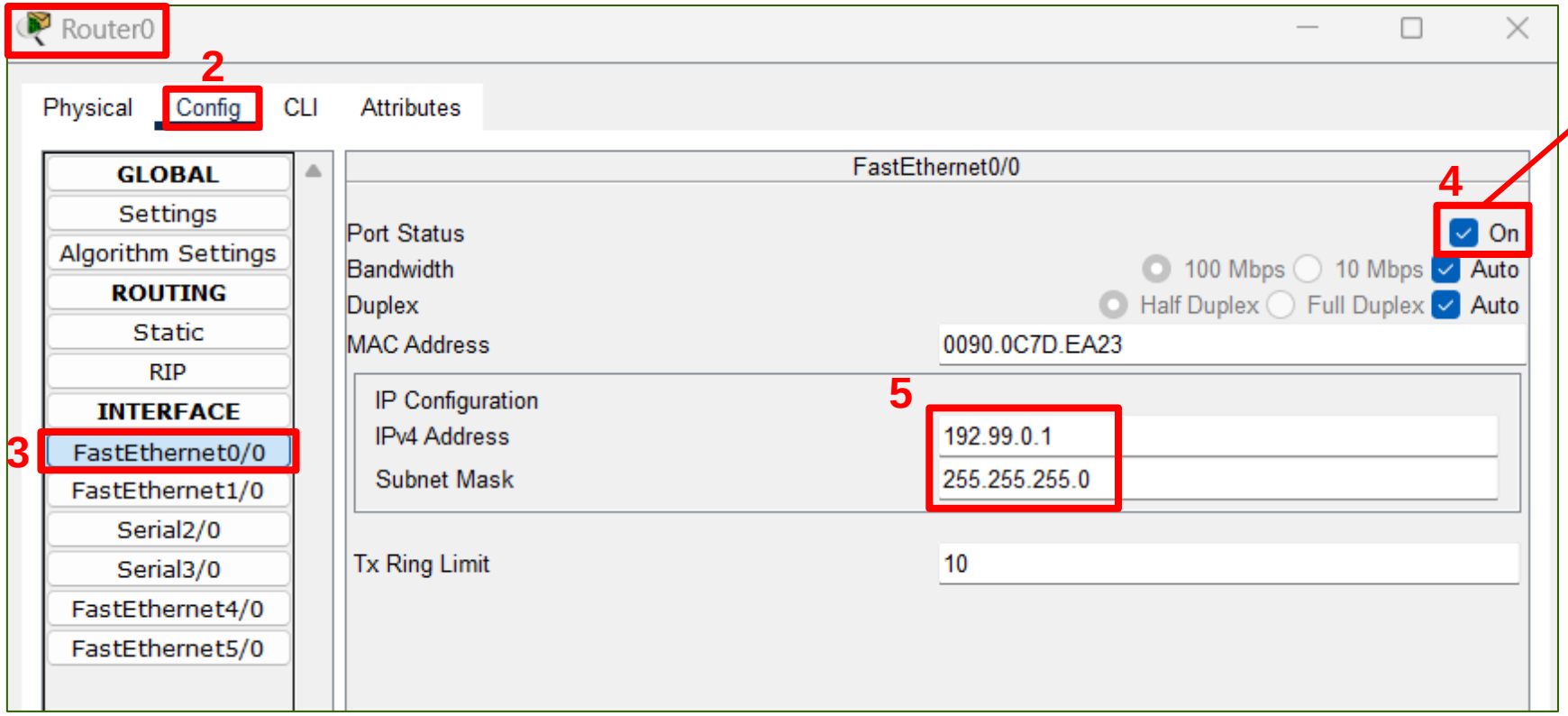
Configuring IPs for the PCs





→ **Assign the rest of the IP addresses to the rest of the PCs.**

Configuring IPs for the Routers



→ **Assign the rest of the IP addresses to the rest of the router interfaces.**

Configuring a Loopback Interface

1. **Create Loopback Interface:**
   - **Router(config)# interface loopback <interface-number>**
     - (You will see messages indicating that the interface and line protocol are now up.)
2. **Assign IP Address**
   - **Router(config-if)# ip address <IP-address> <subnet-mask>**

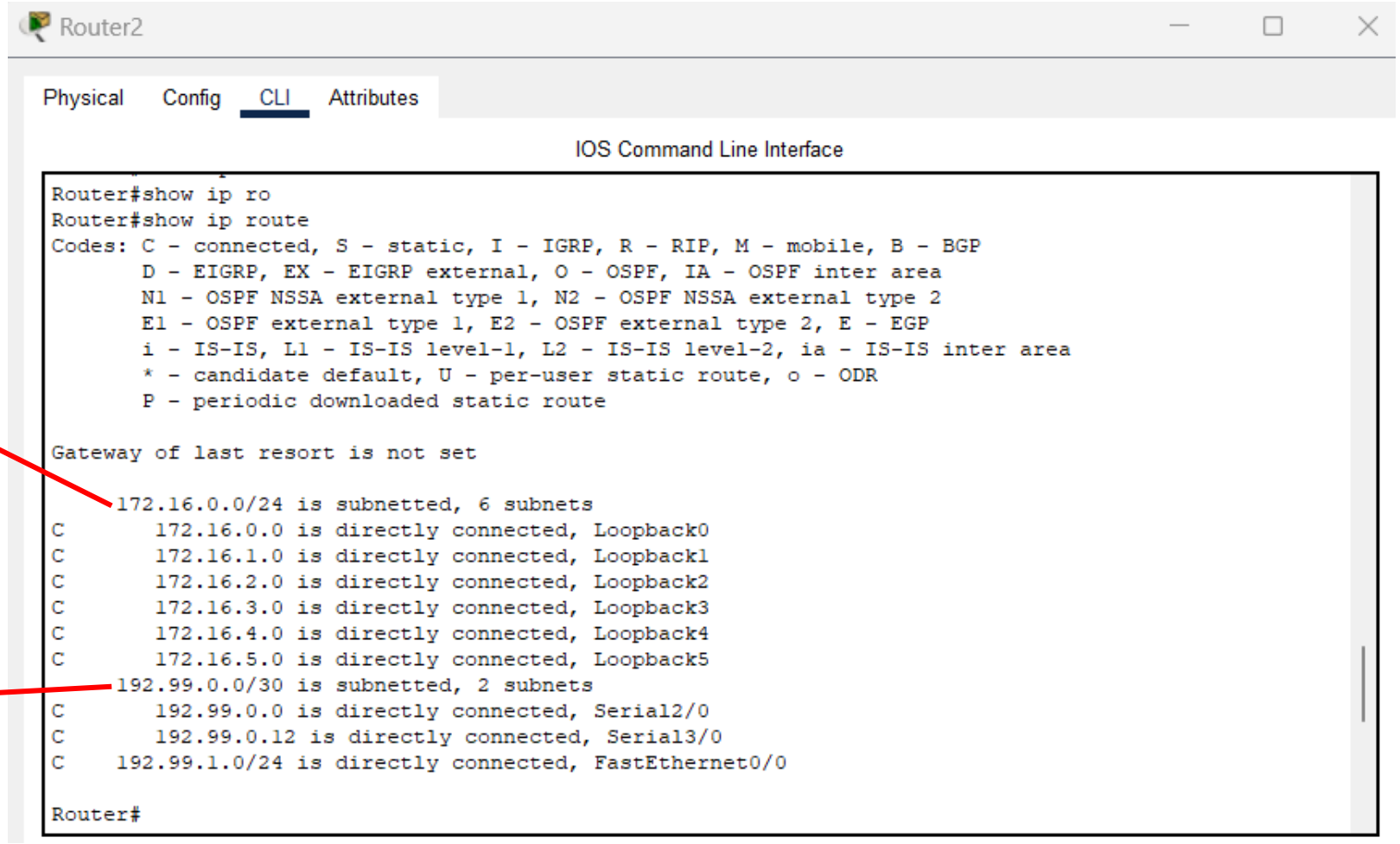
Configuring a Loopback Interface (Cont.)

Loopback 0	Router(config)# interface loopback 0
	Router(config-if)# ip address 172.16.0.1 255.255.255.0
Loopback 1	Router(config)# interface loopback 1
	Router(config-if)# ip address 172.16.1.1 255.255.255.0
Loopback 2	Router(config)# interface loopback 2
	Router(config-if)# ip address 172.16.2.1 255.255.255.0
Loopback 3	Router(config)# interface loopback 3
	Router(config-if)# ip address 172.16.3.1 255.255.255.0
Loopback 4	Router(config)# interface loopback 4
	Router(config-if)# ip address 172.16.4.1 255.255.255.0
Loopback 5	Router(config)# interface loopback 5
	Router(config-if)# ip address 172.16.5.1 255.255.255.0

Verifying the Routing Tables

The 172.16.0.0/24 subnet is divided into 6 directly connected subnets, each assigned to a different loopback interface.

The 192.99.0.0/30 subnet is split into 2 subnets, with 192.99.0.0 on Serial2/0 and 192.99.0.12 on Serial3/0, plus 192.99.1.0/24 on FastEthernet0/0.



Configuring OSPF Routing

1. **OSPF Configuration Command:**
   - **Router(config)# router ospf <PROCESS-ID>**
     - Use a Process ID (1-65535).
2. **Add Networks to OSPF**
   - **Router(config-router)# network <NETWORK-ID> <OSPF-WILDCARD-BITS> area <AREA-ID>**

- **Example Configuration for Router 3:**
  - **Router(config)# router ospf 1**
  - **Router(config-router)# network 192.X.0.8 0.0.0.3 area 0**
  - **Router(config-router)# network 192.X.0.12 0.0.0.3 area 0**
  - **Router(config-router)# network 192.X.2.0 0.0.0.127 area 2**

Configuring OSPF Routing (Cont.)

Router 0	Router(config)# router ospf 1
	Router(config-router)#network 192.X.0.4 0.0.0.3 area 0
	Router(config-router)#network 192.X.0.8 0.0.0.3 area 0
	Router(config-router)#network 192.X.2.128 0.0.0.127 area 3
Router 1	Router(config)# router ospf 1
	Router(config-router)#network 192.X.0.0 0.0.0.3 area 0
	Router(config-router)#network 192.X.0.4 0.0.0.3 area 0
Router 2	Router(config)# router ospf 1
	Router(config-router)#network 192.X.0.0 0.0.0.3 area 0
	Router(config-router)#network 192.X.0.12 0.0.0.3 area 0
	Router(config-router)#network 192.X.1.0 0.0.0.255 area 1
Router 3	Router(config)# router ospf 1
	Router(config-router)#network 192.X.0.8 0.0.0.3 area 0
	Router(config-router)#network 192.X.0.12 0.0.0.3 area 0
	Router(config-router)#network 192.X.2.0 0.0.0.127 area 2

Verifying the Routing Tables

Router2

Physical Config CLI Attributes

IOS Command Line Interface

```
Router#
Router#show ip r
Router#show ip rou
Router#show ip route
Codes: C - connected, S - static, I - IGRP, 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 not set

     172.16.0.0/24 is subnetted, 6 subnets
C       172.16.0.0 is directly connected, Loopback0
C       172.16.1.0 is directly connected, Loopback1
C       172.16.2.0 is directly connected, Loopback2
C       172.16.3.0 is directly connected, Loopback3
C       172.16.4.0 is directly connected, Loopback4
C       172.16.5.0 is directly connected, Loopback5
     192.99.0.0/30 is subnetted, 4 subnets
C       192.99.0.0 is directly connected, Serial2/0
O       192.99.0.4 [110/128] via 192.99.0.2, 00:02:40, Serial2/0
O       192.99.0.8 [110/128] via 192.99.0.14, 00:01:18, Serial3/0
C       192.99.0.12 is directly connected, Serial3/0
C    192.99.1.0/24 is directly connected, FastEthernet0/0
     192.99.2.0/25 is subnetted, 2 subnets
O IA    192.99.2.0 [110/65] via 192.99.0.14, 00:00:53, Serial3/0
O IA    192.99.2.128 [110/129] via 192.99.0.2, 00:01:18, Serial2/0
                     [110/129] via 192.99.0.14, 00:01:18, Serial3/0
```

OSPF cost values reflect routing efficiency, with lower values indicating preferred paths.

The "IA" designation in OSPF routing indicates an Inter-Area route learned from a different OSPF area, facilitating efficient routing across multiple areas.

OSPF Loopback Network Summarization - Option 1

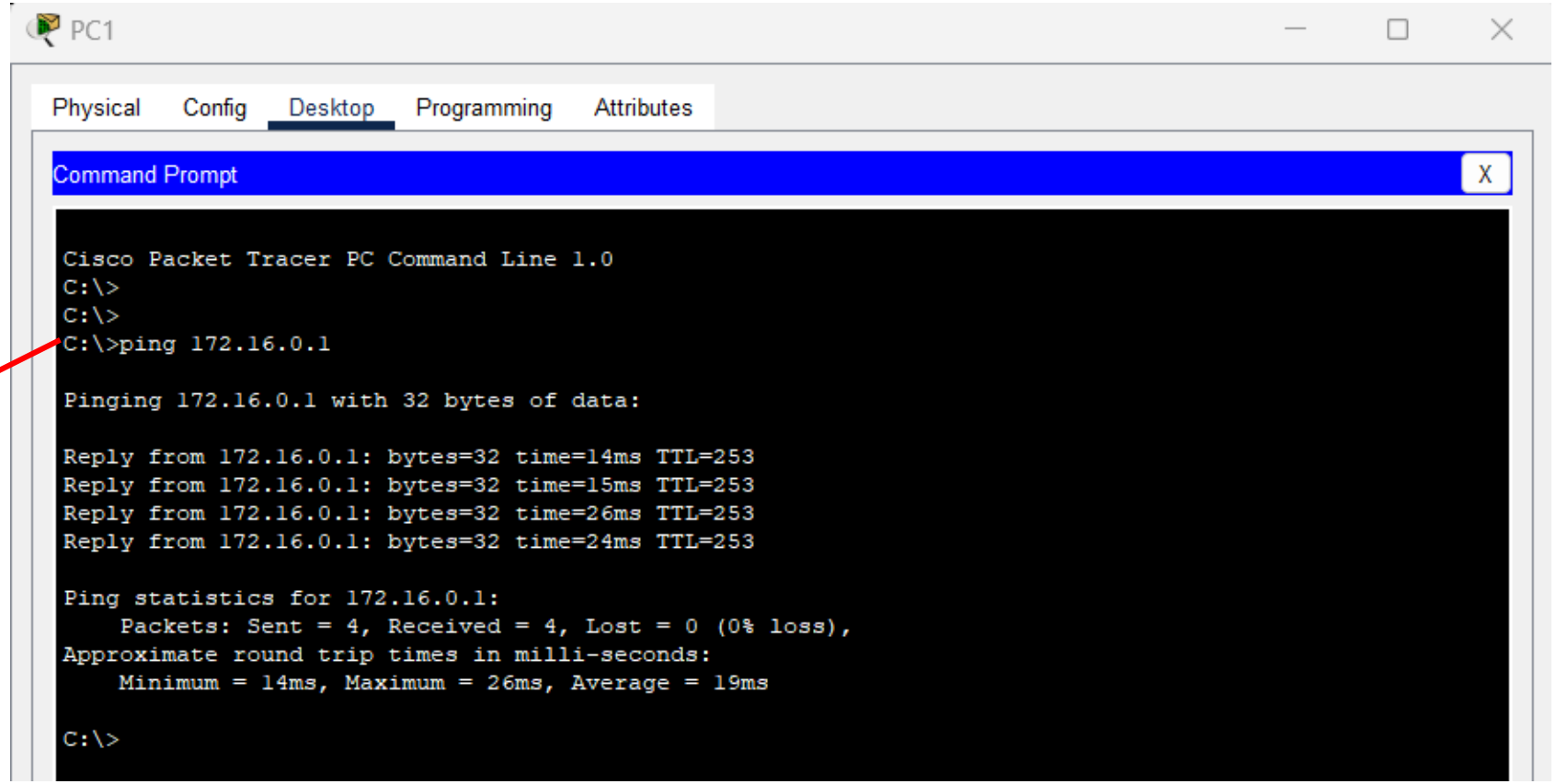
1. **Option 1: Add individual loopback networks to OSPF on Router 2.**
   - **Router(config)# router ospf 1**
   - **Router(config-router)# network 172.16.0.0 0.0.0.255 area 1**
   - **Router(config-router)# network 172.16.1.0 0.0.0.255 area 1**
   - **Router(config-router)# network 172.16.2.0 0.0.0.255 area 1**
   - **Router(config-router)# network 172.16.3.0 0.0.0.255 area 1**
   - **Router(config-router)# network 172.16.4.0 0.0.0.255 area 1**
   - **Router(config-router)# network 172.16.5.0 0.0.0.255 area 1**

OSPF Loopback Network Summarization - Option 2

2. **Option 2: Network Summarization.**
   - **Combine the first four networks into one:**
     - **Router(config)# router ospf 1**
     - **Router(config-router)# network 172.16.0.0 0.0.3.255 area 1**
   - **Combine the last two networks:**
     - **Router(config)# router ospf 1**
     - **Router(config-router)# network 172.16.4.0 0.0.1.255 area 1**

- **Benefits**: Reduces CPU usage and simplifies routing by handling only two summarized networks instead of six individual networks.

Ping to Loopback0

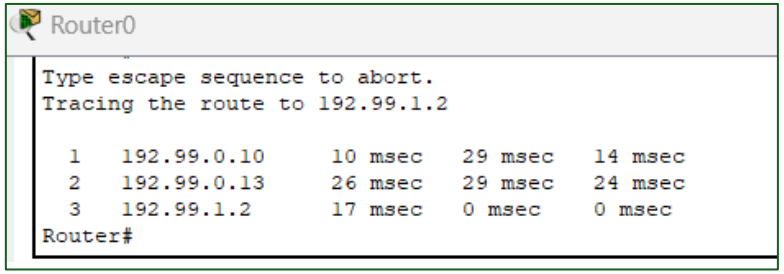


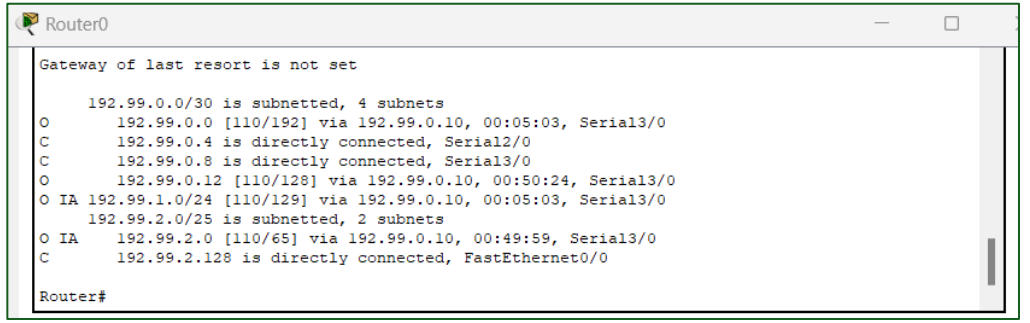
Changing the Cost in OSPF

1. **View Current Routing Table**
   - **Router# sh ip route**
2. **Identify Interface Cost**
   - To change the cost to 5, calculate the necessary bandwidth:
     - $\text{Cost} = \frac{100\ Mbps}{Bandwidth\ (Mbps)}$
     - Set Bandwidth to 20 Mbps (20000 Kbps).
3. **Set the New Bandwidth**
   - **Router(config)# interface Se2/0**
   - **Router(config-if)# bandwidth 20000**

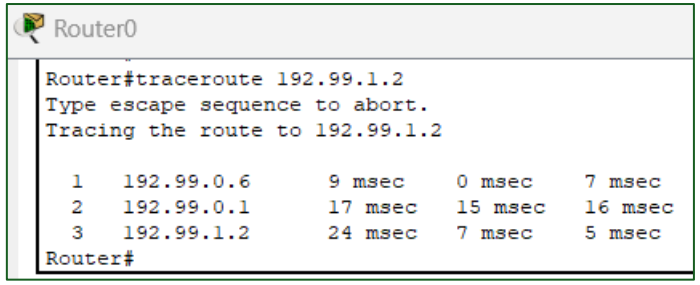
Changing the Cost in OSPF (Cont.)

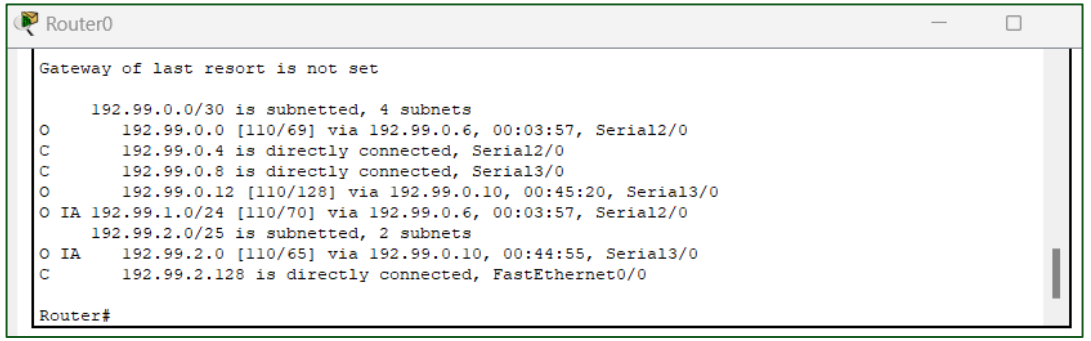
- **Before changing the cost (R0 → R3 → R2)**





- **After changing the cost (R0 → R1 → R2)**





Important Questions

- **Why do we need loopback interfaces?**
  - Loopback interfaces provide a stable, always-up interface for routing protocols, ensuring consistent routing information and connectivity, even if other interfaces are down.

- **What is the router ID for OSPF, and why do we need it?**
  - The router ID uniquely identifies a router in OSPF. It is crucial for OSPF operations, including route calculation and establishing neighbour relationships.

Important Questions (Cont.)

- **Hardcoding Router IDs:**
  - **Router(config)# router ospf 1**
  - **R1: Router(config-router)# router-id 1.1.1.1**
  - **R2: Router(config-router)# router-id 2.2.2.2**
  - **R3: Router(config-router)# router-id 3.3.3.3**

- **Verify the Configuration:**
  - **Router# clear ip ospf process**
  - **Router# show ip ospf**

Saving Configurations

- **Don't forget to save the configurations on your router.**

  → **Router# write**
  → **Router# copy run start**

Video explaining the experiment

https://www.youtube.com/watch?v=1iJ882Xqqm0&t=1132s&ab_channel=TariqOdeh

References

- **Manual for ENCS4130 Computer Networks Laboratory.**
- **Slides from Dr. Amr Slimi.**