# Implementing IP Routing

- Packet Handling and Forwarding
- Describe the process of packet forwarding along the path through a network
- Understand how routers make forwarding decisions based on routing table information
- Explain the concept of route lookup and packet switching in a router
- Routing Table Components
- Interpret the components of a routing table
- Understand routing table entries, including prefixes, network masks, and next-hop addresses
- Explain the significance of routing protocol codes, administrative distances, and route metrics
- Discuss the role of the gateway of last resort in routing decisions
- Routing Table Population
- Understand routing table updates and routing information exchange protocols
- Explain how routing protocols advertise network reachability information

**Hands-On:**

- Use the traceroute (or tracert on Windows) command to trace the path a packet takes from your device to a remote destination. Analyze the output to understand the hops a packet takes through the network.
- Set up a routing simulation with a tool like GNS3. Use static routing to direct traffic through a specific path and observe how routers handle packet forwarding. Change the topology and observe how forwarding decisions change.
- Using a network simulator, observe how routers perform route lookups in their routing tables and switch packets to the appropriate interface. Experiment by adding, removing, and modifying routes in the routing table.
- On a router or a routing simulator, examine the routing table entries using show ip route command. Identify prefixes, network masks, next-hop addresses, and other table components.
- Review different routing protocol metrics like hop count, bandwidth, delay, and reliability. Debate their significance and how they affect the path selection process in a router.
- Configure a default route on a router and demonstrate how it is used as a "gateway of last resort" for packets with no specific matching route in the routing table.
- Using a network simulator, configure dynamic routing protocols (such as OSPF or EIGRP) on routers within a network. Observe how routing tables are populated and updated over time as the network topology changes.

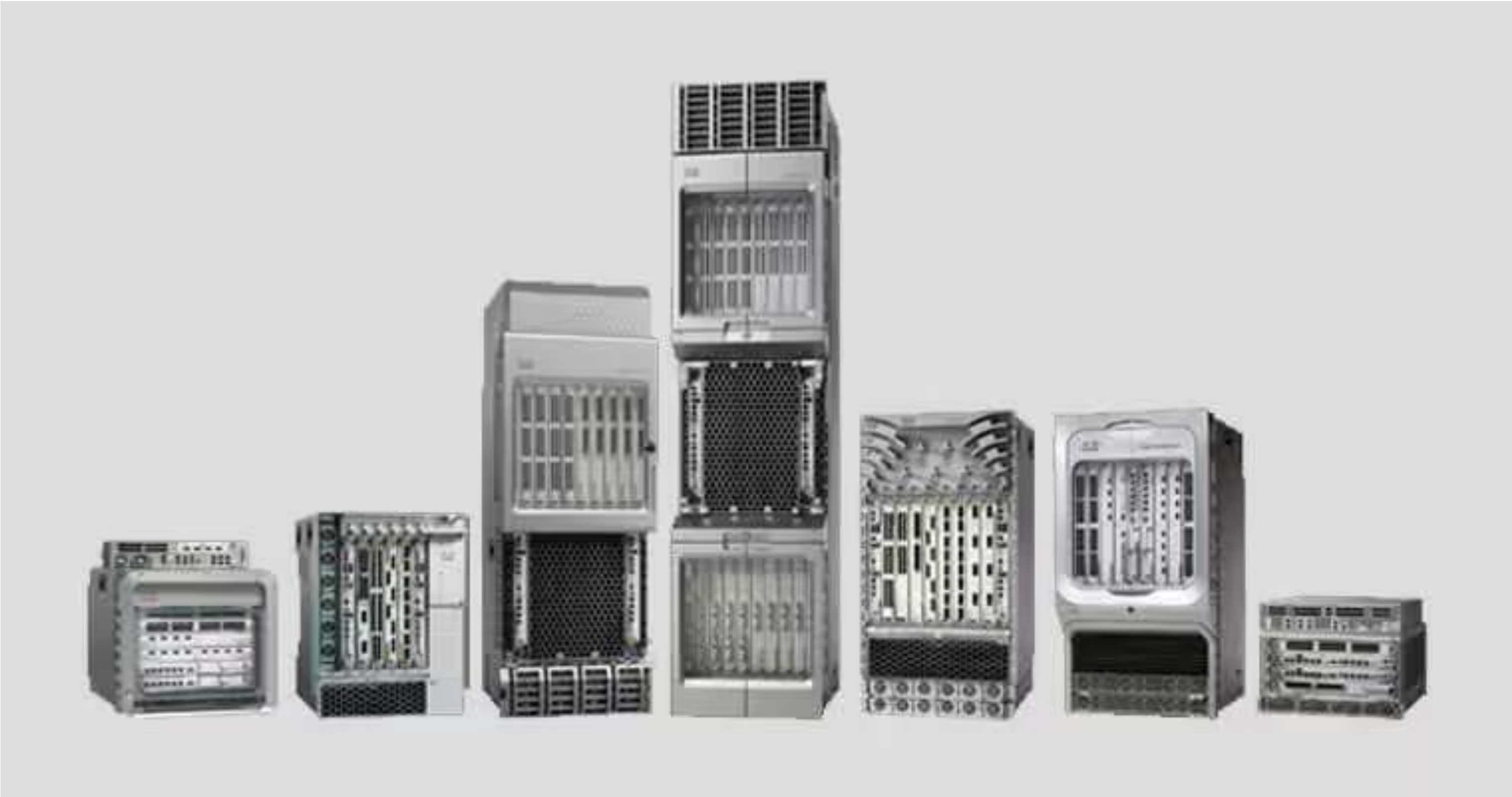
Routing Protocol Configuration

- Configure, Verify, and Troubleshoot Routing Protocols
- Implement and troubleshoot static and dynamic routing protocols for IPv4 and IPv6 networks
- Configure static routes and floating static routes for specific network destinations
- Implement dynamic routing protocols, such as OSPF, EIGRP, and RIPv2, for automatic route propagation
- Verify routing protocol configurations and troubleshoot routing protocol adjacencies and route advertisements
- Compare and contrast routing protocols based on their characteristics, operation modes, and convergence behaviors
- Basic Connectivity Troubleshooting
- Troubleshoot basic Layer 3 end-to-end connectivity issues in a network
- Identify common network connectivity problems, such as routing table inconsistencies and interface issues
- Use troubleshooting tools, such as ping and traceroute, to diagnose and resolve connectivity issues

# What is a Router?

- A Networking Device, works at the layer 3 (Network Layer) of the OSI reference model, used to connecting networks and forward packets.
- Cisco Systems, Juniper Networks, Huawei, Arista Networks, HPE/Aruba, Nokia, Mikrotik.

# Cisco Routers (ISR)



# Juniper Networks Product Portfolio

**Application Acceleration Data Centre**

**Secure Access SSL VPN**

**Intrusion Prevention**

**Integrated Firewall / IPSec VPN**

**Edge Service Routers**

**Application Acceleration**

**Session Border Controllers**

**BRAS & Circuit Aggregation**

**Small/Med Circuit Aggregation**

**Large Core Metro Aggregation**

Juniper your Net

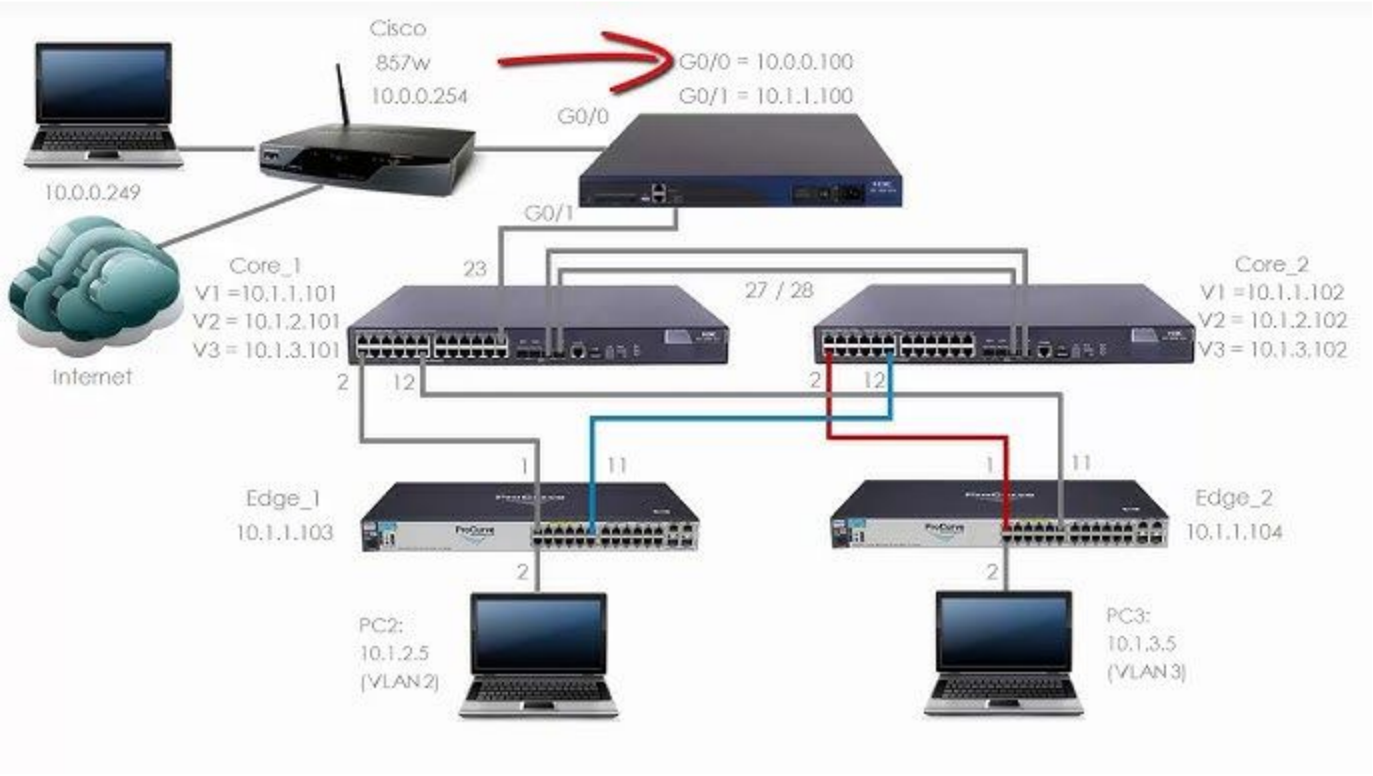
# Network Operating Systems (NOS)

Cisco **IOS, IOS-XE,** IOS-XR, Nexus, CatOS, MerakiOS

Juniper - JunOS

Arista - EOS

https://buy.hpe.com/in/en/networking/routers/c/4172265



Cisco
857w
10.0.0.254
G0/0 = 10.0.0.100
G0/1 = 10.1.1.100
G0/0
10.0.0.249
G0/1
Internet
Core_1
V1 =10.1.1.101
V2 = 10.1.2.101
V3 = 10.1.3.101
23
27 / 28
Core_2
V1 =10.1.1.102
V2 = 10.1.2.102
V3 = 10.1.3.102
2
12
2
12
1
11
1
11
Edge_1
10.1.1.103
Edge_2
10.1.1.104
2
2
PC2:
10.1.2.5
(VLAN 2)
PC3:
10.1.3.5
(VLAN 3)

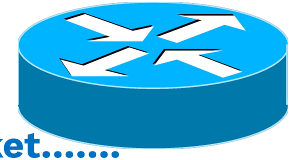
# What does a Router do ?

## (Peeping into the life of a Router)

- find path

forward packet, forward packet, forward packet.....

- find alternate path



forward packet, forward packet, forward packet.......

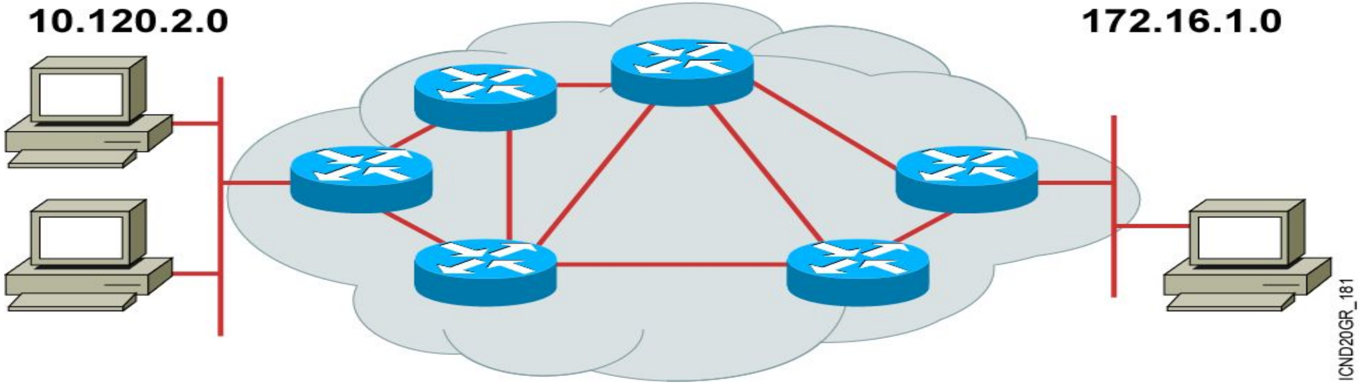
- repeat until powered off

# What is Routing ?

- Routing is the process of moving packets across a network from a source to a destination.
- Routing requires a IP Address both Source & Destination address for efficient routing
- Routing Protocols are used for routing IP packets across an Internetwork

    - Ex: RIP, EIGRP, OSPF, IS-IS, BGP for IPv4 Routing
    - Ex: RIPng, EIGRPv6, OSPFv3, IS-ISv6, BGP4+ for IPv6

# What is Routing?




To route, a router needs to do the following:

- Know the Destination address
- Identify the sources it can learn from
- Discover possible routes
- Select the best route to the Destination Network
- Maintain and verify routing information

# How Routing works?

1. **Source Device** creates a data L3 packet with a destination IP.

2. The packet is sent to a **router** (or default gateway).

3. The router checks its **routing table** to decide:

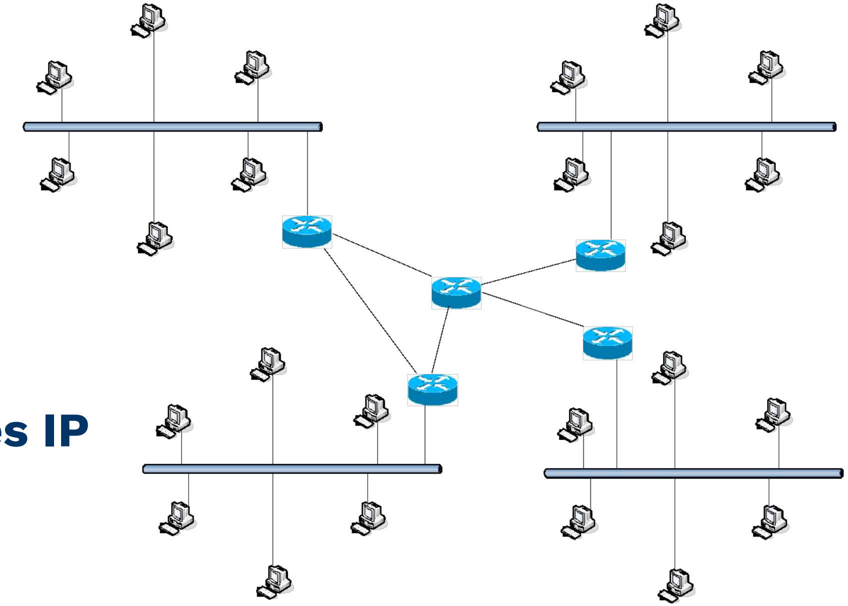
    ○ Is the destination on a directly connected network?

    ○ If not, where should it forward the packet next (next-hop)?

4. The router forwards the packet toward the destination based on the best available route.

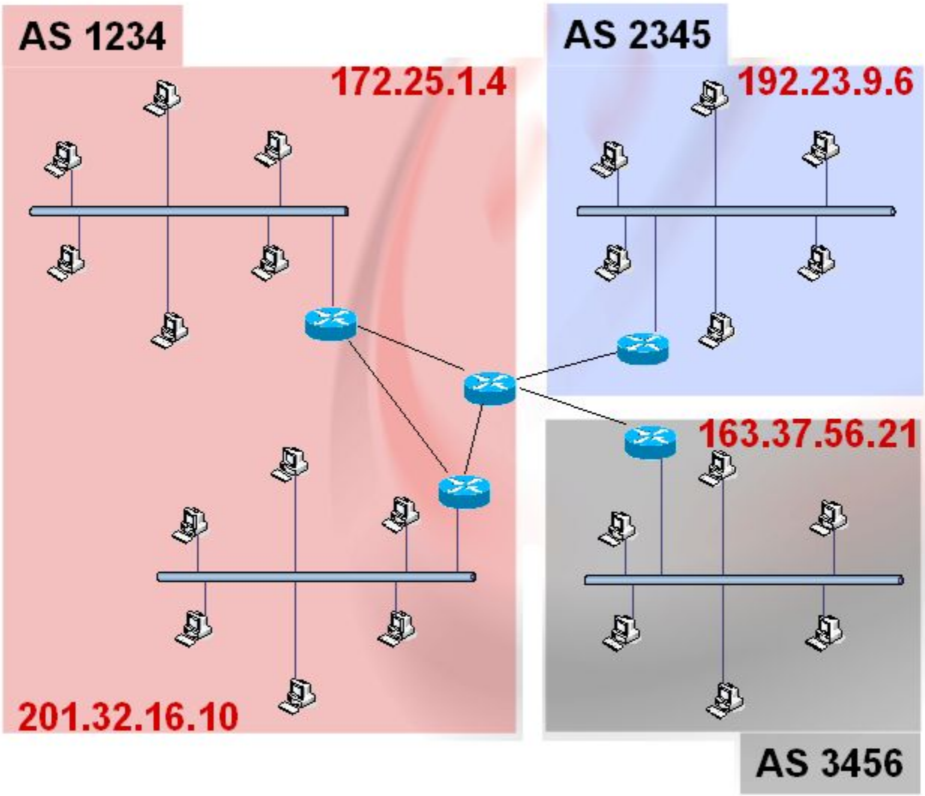
# Interconnected Networks (Internetwork)

**Each network can link to other networks via its Router.**




**Each segment receives IP addresses.**

# Administrative Grouping (AS Numbers)




**Administrative Grouping is done using ASN, AS numbers are administrative boundary of a Network**

**AS 1234: 172.25.1.4, 201.32.16.10**

**AS 2345: 192.23.9.6**

**AS 3456: 163.37.56.21**

# Layer-3 Routing

Layer-3 routing is the process of forwarding a packet from one network to another network, based on the Network layer header.

Routers build routing tables to perform forwarding decisions, which contain the following:

- The destination network and subnet mask
- The next hop router to get to the destination network
- Routing metrics and Administrative Distance

Note that **Layer-3 forwarding is based on the destination network**, and not the destination host.

The routing table is concerned with two types of Layer-3 protocols:

- **Routed protocols -** assigns logical addressing to devices, and routes packets between networks. Examples include IP, IPv6 and IPX.
- **Routing protocols -** dynamically builds the information in routing tables. Examples include RIP, EIGRP, OSPF, ISIS, BGP

Layer 3 (only routing works in Layer 3)

# Routing Table

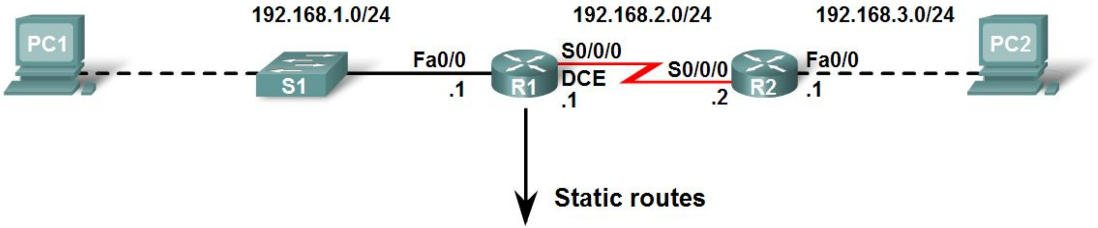
Routing Table is stored in RAM & contains information about:

- **Directly connected networks** - this occurs when a device is connected to another router interface
- **Remotely connected networks** - this is a network that is not directly connected to a particular router
- **Detailed information** about the networks include source of information, network address & subnet mask, and Ip address of next-hop router

**#show ip route** command is used to view a routing table

# #show ip route

Connected and Static Routes




```
R1#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

C    192.168.1.0/24 is directly connected, FastEthernet0/0
C    192.168.2.0/24 is directly connected, Serial0/0/0
S    192.168.3.0/24 [1/0] via 192.168.2.2
```

# What is a Protocol?

- Set of rules that define the communications process
- Defines the structure or pattern for the data transferred  functions or processes that need to be carried out in order to implement the data exchange information required by processes in order for them to accomplish this.
- All data is transmitted in the same way irrespective of what the data refers to, whether it is clear or encrypted.

A **Distance Vector Routing Protocol** determines the best path to a destination based on **distance (hop count)** and **direction (vector)**.

Routers periodically share their **routing tables** with **directly connected neighbors** to update routes.

## Distance Vector Routing Protocol:

- All the routers periodically send their complete routing tables to only their neighboring routers.
- Routers use the received information to determine whether any changes need to be made to their own routing table.

## Link-state Routing Protocol:

- Each router sends the state of its own interfaces (links) to all other routers in an area only when there is a change.
- Each router uses the received information to recalculate the best path to each network and then saves this information in its routing table.

## Classful Routing Protocol:

- Routing updates sent do not include the subnet mask.
- Subnets are not advertised to a different major network.

RIP Version 1 (RIPv1) is a classful routing protocol.

## Classless Routing Protocol:

- Routing updates sent include the subnet mask.
- Subnets are advertised to a different major network.

RIPv2, EIGRP, OSPF &  BGP are classless routing protocols.

# Best Path to a destination

The best route selected from various routing protocols for a specific destination is chosen by considering the following four criteria:

- Valid next-hop IP address.
- Administrative Distance (AD)
- Metric (Lowest Hop Count, Bandwidth, Delay, Cost)....
- Prefix

# Administrative Distance (AD)

Cisco routers use a value called administrative distance to select the best path when they learn of two or more routes to the same destination with the same prefix from different routing protocols.

- Administrative distance rates a routing protocol's *believability*.
- Cisco has assigned a default administrative distance value to each routing protocol supported on its routers.
- Each routing protocol is prioritized in the order of most to least believable.

## Administrative Distance (AD) Cisco default

| | |
|---|---|
| Connected Interface | 0 |
| Static Route | 1 |
| Default Route | 1 |
| External BGP | 20 |
| EIGRP (Internal) | 90 |
| OSPF | 110 |
| RIPv1, RIPv2 | 120 |
| External EIGRP | 170 |
| Internal BGP | 200 |

# Types of IP Routing

**Static Routing**

- Routes are manually configured by a network admin.

  Static route

**Default Routing**

- A "catch-all" route used when no specific match is found in the routing table.

  Default route

**Dynamic Routing**

- Routers learn routes automatically using protocols (e.g., OSPF, EIGRP, BGP).

**Static routing** is a type of routing in which the network routes are manually configured and set by the Network Administrator.

Is used in small networks, with very less number of destination networks.

# Static Route | Default Route

# Configuring IPv4 Static Routes

***Router(config)# ip route network-address subnet-mask {next-hop-ip-address | exit-interface }***

| Parameter | Description |
|---|---|
| `network-address` | Destination network address of the remote network to be added to the routing table. |
| `subnet-mask` | Subnet mask of the remote network to be added to the routing table. The subnet mask can be modified to summarize a group of networks. |
| `ip-address` | Commonly referred to as the next-hop router's IP address. |
| `exit-interface` | Outgoing interface that is used to forward packets to the destination network. |

# When to use Static Routes:

- In small networks that are not expected to grow
- When network only consists of a few routers
- Network is connected to internet only through one ISP
- To route traffic to & from stub networks.
- To make a backup route for dynamic routing protocol
- To configure a "catch all" route (i.e; default route) when no other route in the routing table match

# Static v/s Dynamic Routing

- Advantages of **static routing**
  - Easy to configure
  - No extra resources are needed, uses less router memory | CPU
  - More secure
- Disadvantages of **static routing**
  - Network changes require manual reconfiguration
  - Does not scale well in large topologies

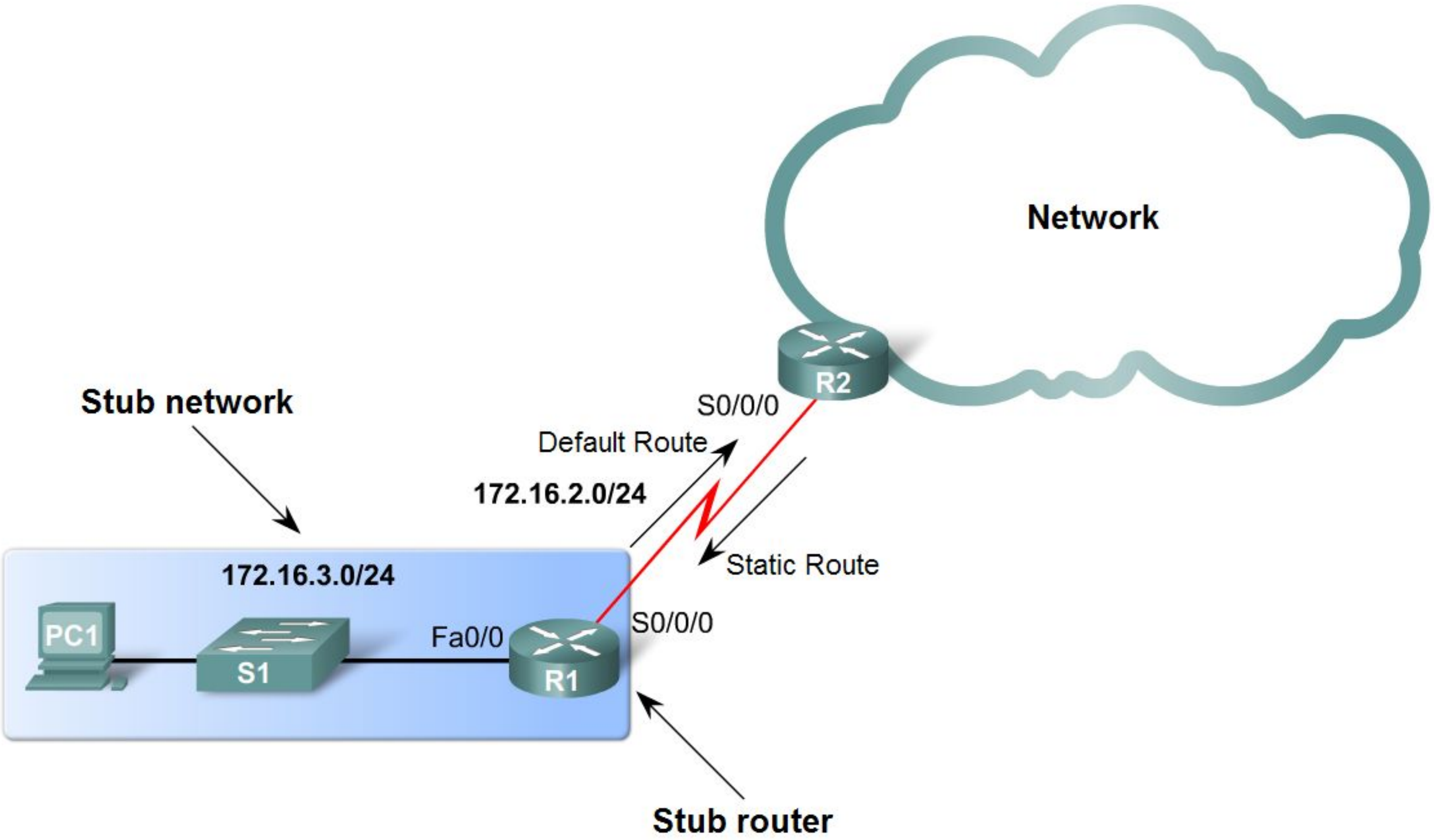
# Example

**R1(config)#ip route 192.168.2.0 255.255.255.0 192.168.1.2**

**Verification:**

**R1#show ip route**

# Default Route



## Dynamic Routing Protocols

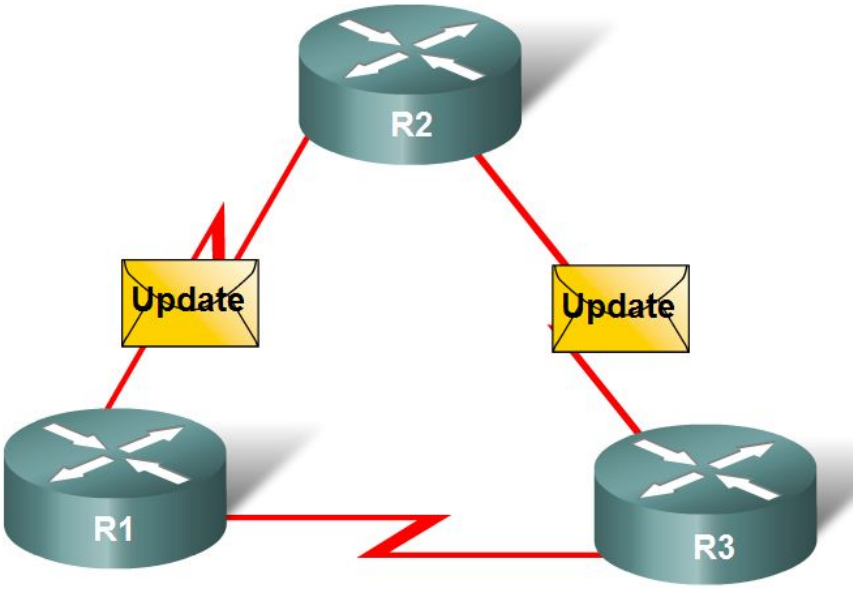
Are used by routers to **automatically discover and maintain routes to a destination network.**

- **RIP**
- **EIGRP**
- **OSPF**
-

# Dynamic Routing Protocols

- Function(s) of Dynamic Routing Protocols:
- Dynamically share information between routers.
- Automatically update routing table when topology changes.
- Determine best path to a destination.

Routers Dynamically Pass Updates



The **purpose of a dynamic routing protocol** is to:

- Discover remote networks
- Maintaining up-to-date routing information
- Choosing the best path to destination networks (Lowest Delay, Highest Bandwidth, Lowest Cost, Lowest Hop Count)
- Ability to find a new best path if the current path is no longer available

# Components of a routing protocol

## (Routing) Algorithm

- In the case of a routing protocol algorithms are used for facilitating routing information and best path determination

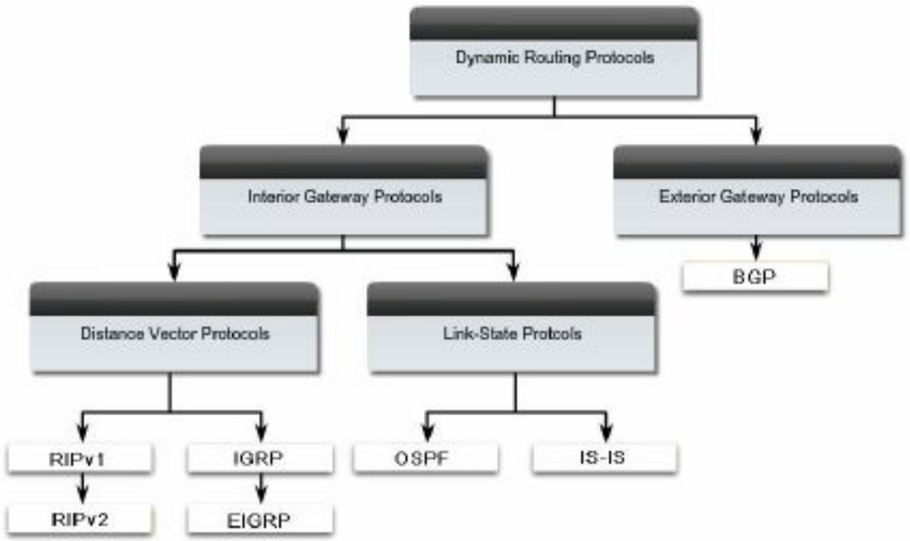
  OSPF - Dijkstra's SPF Algorithm (Cost), EIGRP - DUAL Algorithm (b/w and delay), RIP - Bellman Ford algorithm (Hop)

## Routing protocol messages

- These are messages for discovering neighbors and exchange of routing information *(carry routing updates)*

# Classifying Routing Protocols

- RIP(v1,v2)
- IGRP (Deprecated)
- EIGRP
- OSPF
- IS-IS
- BGP

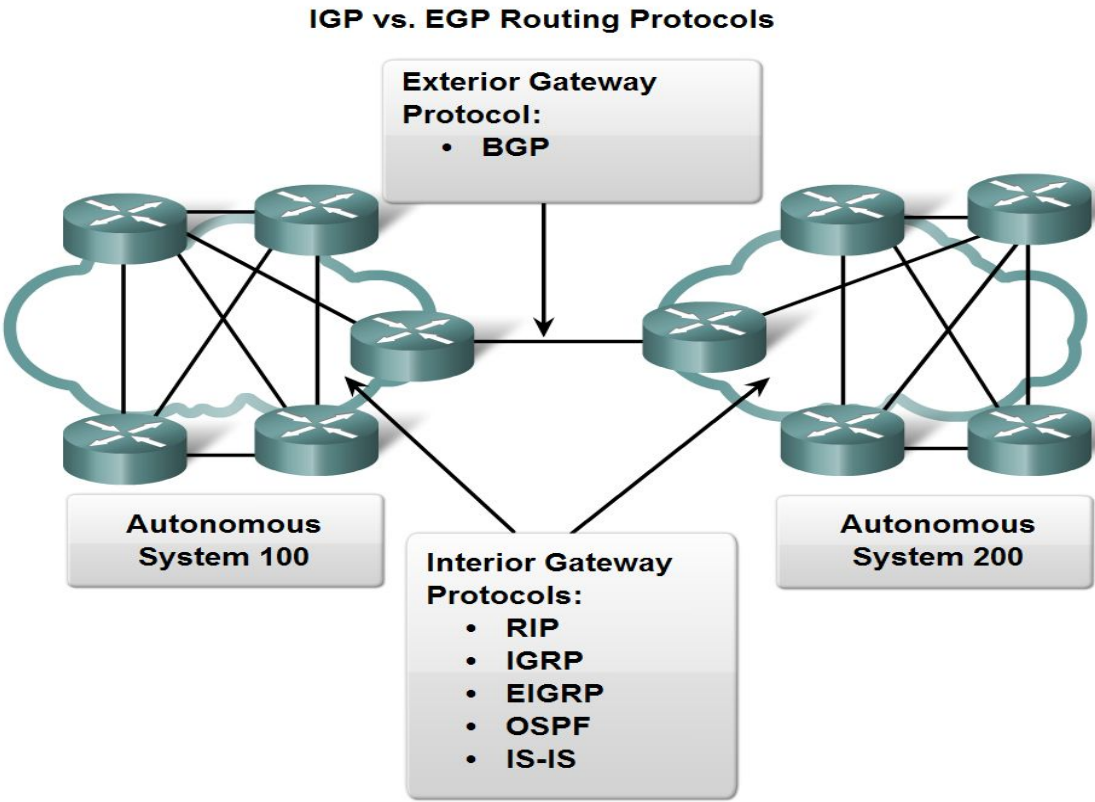


# Classifying IP Routing Protocols

Types of IP Routing Protocols

- Interior Gateway Protocol (IGP)
- Exterior Gateway Protocol (EGP)

**Autonomous System (AS)** is a group of routers under the control of a single authority.



# Classifying IP Routing Protocols

## Interior Gateway Routing Protocols (IGP)

Used for routing inside an autonomous system & used to route within the individual networks themselves.

Eg: RIP, IGRP, EIGRP, OSPF, ISIS

## Exterior Routing Protocols (EGP)

Used for routing between autonomous systems

Eg: BGPv4

RIP - Routing Information Protocol

EIGRP - Enhanced Interior Gateway Routing Protocol

OSPF - Open Shortest Path First

ISIS - Integrated Intermediate Systems - Intermediate Systems

BGP - Border Gateway Protocol

# Classifying IP Routing Protocols

## Classful routing protocols

- **Does NOT send** subnet mask in routing updates
- RIPv1, IGRP (not used in modern networks)
- 192.168.1.0/30 (WAN Links)  172.16.1.0/30

  192.168.1.0/24 (Default subnet mask) 172.16.0.0/16

## Classless routing protocols

- **Does send** subnet mask in routing updates
- RIPv2, EIGRP, OSPF, ISIS

RIP - Routing Information Protocol

EIGRP - Enhanced Interior Gateway Routing Protocol

OSPF - Open Shortest Path First

IS-IS - Integrated Intermediate Systems - Intermediate Systems

BGP - Border Gateway Protocol

# Routing Protocol Features

- **Convergence** is defined as when all routers' routing tables are at **a state of consistency**
- **Metric:** A value used by a routing protocol to determine which routes are better than others.
  - **RIP** - Hop Count
  - **IGRP/ EIGRP** - K1, K2, K3, K3, K5 (K1 = Bandwidth, K3 = Delay)
  - **OSPF** - Cost of the Link

Metrics used by routing protocols: **Bandwidth, Cost, Delay, Hop count, Load, Reliability**

# Metric v/s Administrative Distance (AD)

- **Purpose of a metric**

  It's a calculated value **used to determine the best path** to a destination (within the Protocol)

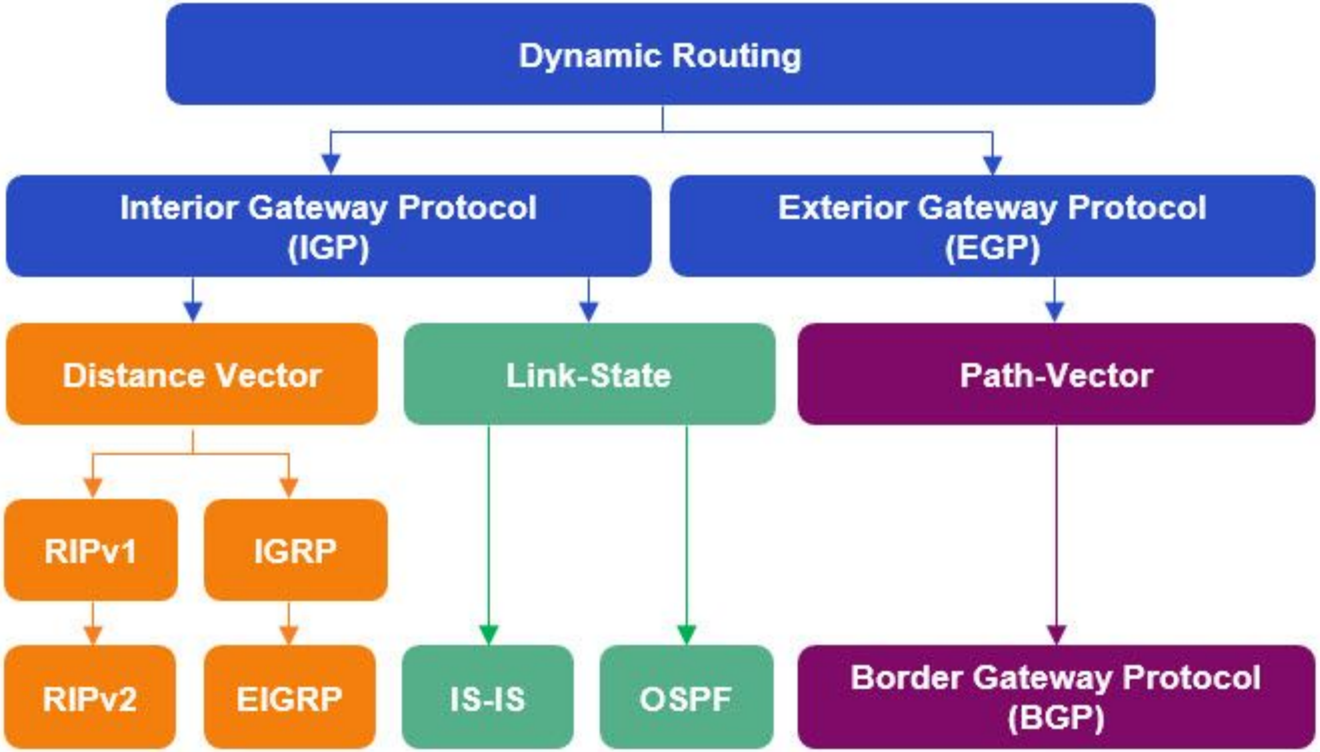
- **Purpose of Administrative Distance (AD)**

  It's a numeric value that **specifies the preference of a particular route (Between 2 different protocols)**

Administrative Distance: (Cisco)

- 0 for directly connected networks
- 1 for static / default routes
- 20 for external BGP
- 90 for Internal EIGRP
- 110 for OSPF
- 115 for ISIS
- 120 for RIP
- 170 for external EIGRP
- 200 for internal BGP

Dynamic I



Dynamic Routing
Interior Gateway Protocol (IGP)
Exterior Gateway Protocol (EGP)
Distance Vector
Link-State
Path-Vector
RIPv1
IGRP
RIPv2
EIGRP
IS-IS
OSPF
Border Gateway Protocol (BGP)

IGP

→ Distance Vector Routing Protocols: RIPv1, RIPv2, IGRP

→ Link State Routing Protocols: OSPF, ISIS

→ Hybrid / Advanced Distance Vector Routing Protocol: EIGRP

A **Distance Vector** is a type of routing algorithm used in computer networks to determine the best path for data to travel across a network. Bellman Ford algorithm.

It works by having each router maintain a table that lists the best-known distance (means Hop Count) to each destination in the network.

The router exchanges this information with its neighbors periodically, hence the name "distance vector."

# Features

**Distance Vector Table**: Each router has a table containing the distance (or cost) to reach each network destination and the next hop along the way.

**Vector**: In this context, a vector refers to the set of distances (or metrics) and corresponding next hops from the router to each destination.

**Periodic Updates**: Routers send updates to their immediate neighbors, sharing their distance vector (a list of destination networks, distance, and next hop).

**Routing Decision**: Each router updates its distance vector based on the information it receives from its neighbors. It selects the next hop that offers the shortest distance to the destination.

**Convergence**: Over time, the network converges to the optimal routing paths, but it can take some time for all routers to have the most accurate and up-to-date information, which can lead to routing loops in some cases.

# Distance Vector Routing Protocols

- **The Meaning of Distance Vector**:

  A router using distance vector routing protocols knows 2 things:

  - **Distance** to final destination
  - **Vector, or direction,** traffic should be directed

  **Eg. RIPv1, RIPv2, IGRP**

# Characteristics of Distance Vector routing protocols:

- Periodic updates (RIP sends updates every 30 seconds)
- Neighbors
- Broadcast updates (destination address 255.255.255.255)
- Entire routing table is included with routing update

# Routing Protocol Characteristics

- Criteria used to compare routing protocols includes
  - Time to convergence
  - Scalability
  - Resource usage (Processor, RAM consumption)
  - Implementation & maintenance

**Advantages of Distance Vector:**

- Simple to implement.
- Works well in smaller networks with fewer routers.

**Disadvantages:**

- Slow convergence (may take a long time for network changes to propagate).
- Susceptible to routing loops (though techniques like Split Horizon, Route Poisoning, and Holddown timers can help mitigate this).
- Not scalable for very large networks.

FastEthernet -100 Mbps

# Cisco Network OS

- **IOS - Internetwork Operating System (Router, Switches, Firewalls, Access Points).**
- CatOS - Catalyst OS for Older Switches.
- NexusOS - Data Center Switches
- MerakiOS - Meraki
- IOS XE - high end routers
- IOS XR - for High End Routers

Juniper - JUNOS

Arista - EOS

Nokia - SR OS

User Exec Mode

```
Router>
```

```
Router>
Router>enable
Router#
Router#disable
Router>
Router>enable
```

Router0

Physical Config CLI Attributes

IOS Command Line Interface

```
  send          Send a message to other tty lines
  setup         Run the SETUP command facility
  show          Show running system information
  ssh           Open a secure shell client connection
  telnet        Open a telnet connection
  terminal      Set terminal line parameters
  traceroute    Trace route to destination
  undebug       Disable debugging functions (see also 'debug')
  vlan          Configure VLAN parameters
  write         Write running configuration to memory, network, or terminal
Router#
Router#
Router#
Router#show version
Cisco IOS Software, 1841 Software (C1841-ADVIPSERVICESK9-M), Version 12.4(15)T1, RELEASE SOFTWARE (fc2)
Technical Support: http://www.cisco.com/techsupport
Copyright (c) 1986-2007 by Cisco Systems, Inc.
Compiled Wed 18-Jul-07 04:52 by pt_team

ROM: System Bootstrap, Version 12.3(8r)T8, RELEASE SOFTWARE (fc1)

System returned to ROM by power-on
System image file is "flash:c1841-advipservicesk9-mz.124-15.T1.bin"


This product contains cryptographic features and is subject to United
States and local country laws governing import, export, transfer and
use. Delivery of Cisco cryptographic products does not imply
third-party authority to import, export, distribute or use encryption.
Importers, exporters, distributors and users are responsible for
compliance with U.S. and local country laws. By using this product you
agree to comply with applicable laws and regulations. If you are unable
to comply with U.S. and local laws, return this product immediately.

A summary of U.S. laws governing Cisco cryptographic products may be found at:
http://www.cisco.com/wwl/export/crypto/tool/stqrg.html
 --More--
```

Top

teams.microsoft.com is sharing your screen. Stop sharing Hide

32°C
Haze

Search

Router0

Physical Config CLI Attributes

IOS Command Line Interface

```
Cisco 1841 (revision 5.0) with 114688K/16384K bytes of memory.
Processor board ID FTX0947Z18E
M860 processor: part number 0, mask 49
2 FastEthernet/IEEE 802.3 interface(s)
4 Low-speed serial(sync/async) network interface(s)
191K bytes of NVRAM.
63488K bytes of ATA CompactFlash (Read/Write)

Configuration register is 0x2102

Router#
Router#
Router#show run
Router#show running-config
Building configuration...

Current configuration : 832 bytes
!
version 12.4
no service timestamps log datetime msec
no service timestamps debug datetime msec
no service password-encryption
!
hostname Router
!
!
!
!
!
!
!
!
no ip cef
no ipv6 cef
!
!
 --More--
```

Router0

Physical Config CLI Attributes

IOS Command Line Interface

```
Router#
Router#show run
Building configuration...

Current configuration : 832 bytes
!
version 12.4
no service timestamps log datetime msec
no service timestamps debug datetime msec
no service password-encryption
!
hostname Router
!
!
!
!
!
!
!
!
no ip cef
no ipv6 cef
!
!

Router#
Router#show ip interface brief
Interface              IP-Address      OK? Method Status                Protocol
FastEthernet0/0        unassigned      YES unset  administratively down down
FastEthernet0/1        unassigned      YES unset  administratively down down
Serial0/0/0            unassigned      YES unset  administratively down down
Serial0/0/1            unassigned      YES unset  administratively down down
Serial0/1/0            unassigned      YES unset  administratively down down
Serial0/1/1            unassigned      YES unset  administratively down down
Vlan1                  unassigned      YES unset  administratively down down
Router#
```

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Top

Router0

Physical Config CLI Attributes

IOS Command Line Interface

```
!
!
!
!
no ip cef
no ipv6 cef
!
!

Router#
Router#show ip interface brief
Interface              IP-Address      OK? Method Status                Protocol
FastEthernet0/0        unassigned      YES unset  administratively down down
FastEthernet0/1        unassigned      YES unset  administratively down down
Serial0/0/0            unassigned      YES unset  administratively down down
Serial0/0/1            unassigned      YES unset  administratively down down
Serial0/1/0            unassigned      YES unset  administratively down down
Serial0/1/1            unassigned      YES unset  administratively down down
Vlan1                  unassigned      YES unset  administratively down down
Router#
Router#
Router#sh ip int bri
Interface              IP-Address      OK? Method Status                Protocol
FastEthernet0/0        unassigned      YES unset  administratively down down
FastEthernet0/1        unassigned      YES unset  administratively down down
Serial0/0/0            unassigned      YES unset  administratively down down
Serial0/0/1            unassigned      YES unset  administratively down down
Serial0/1/0            unassigned      YES unset  administratively down down
Serial0/1/1            unassigned      YES unset  administratively down down
Vlan1                  unassigned      YES unset  administratively down down
Router#
Router#
Router#
Router#configure terminal
Enter configuration commands, one per line.  End with CNTL/Z.
Router(config)#
Router(config)#
```

Copy Paste

Top

teams.microsoft.com is sharing your screen. Stop sharing Hide

32°C Haze Search ENG IN 12:28 13-02-2025

Configuring fastethernet interface

R1(config)#int fa0/0

R1(config-if)#ip address 192.168.1.1 255.255.255.0

R1(config-if)#no shutdown

R1#write memory

Or

R1#wr

# Lab 1

Router>enable
Router#configure terminal
Router(config)#hostname R1
R1(config)#
R1(config)#interface fastethernet 0/0
R1(config-if)#ip address 192.168.1.1 255.255.255.0
R1(config-if)#no shutdown

Verification

#show run (Or) R1(config-if)#do show run

R1#show ip interface brief (or) R1(config-if)#do sh ip int bri

R1#write memory

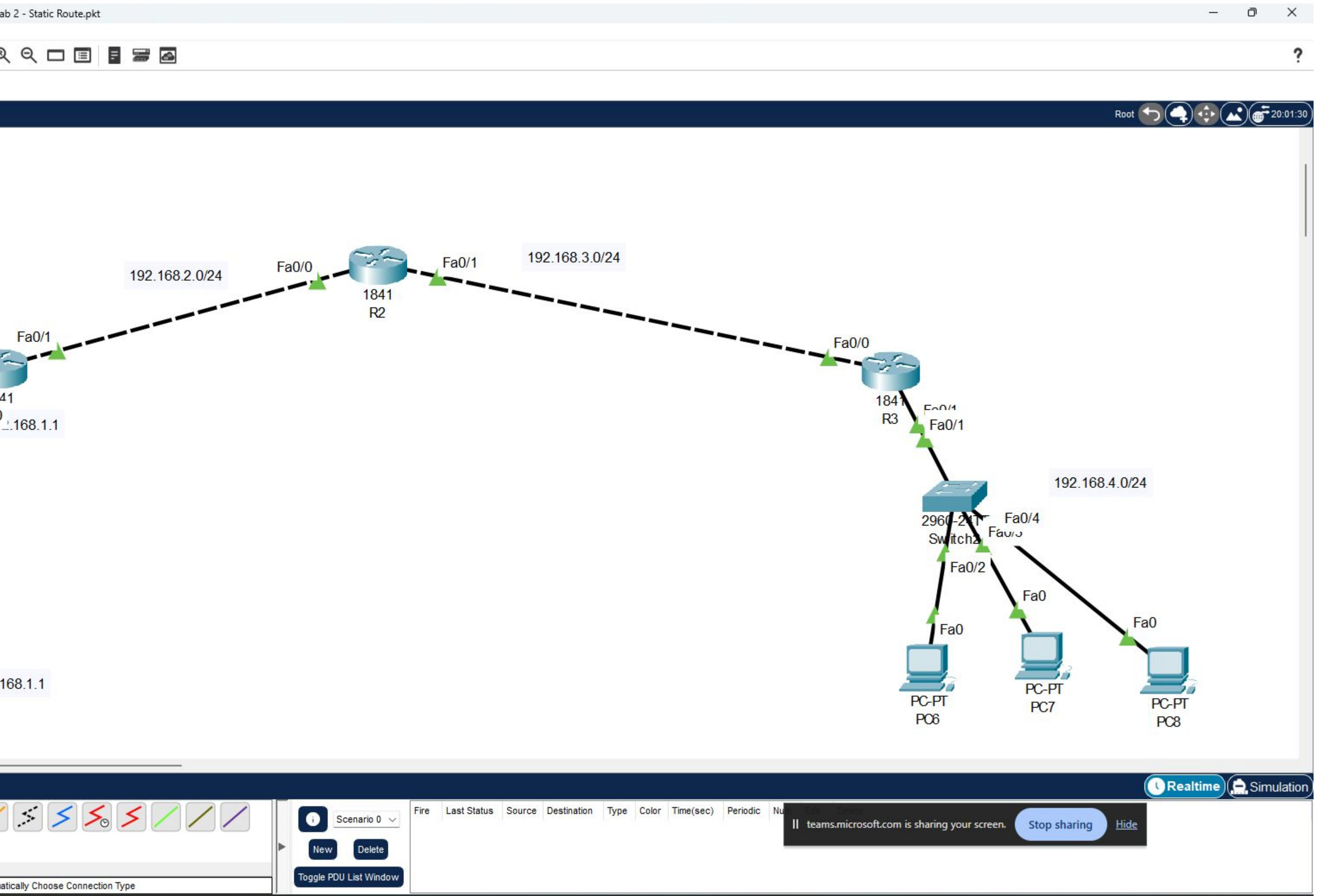
PC1

Physical | Config | Desktop | Programming | Attributes

Command Prompt

```
Cisco Packet Tracer PC Command Line 1.0
C:\>
C:\>
C:\>ipconfig

FastEthernet0 Connection:(default port)

   Connection-specific DNS Suffix..:
   Link-local IPv6 Address.........: FE80::2E0:A3FF:FEC2:6455
   IPv6 Address....................: ::
   IPv4 Address....................: 192.168.1.2
   Subnet Mask.....................: 255.255.255.0
   Default Gateway.................: ::
                                     192.168.1.1

Bluetooth Connection:

   Connection-specific DNS Suffix..:
   Link-local IPv6 Address.........: ::
   IPv6 Address....................: ::
   IPv4 Address....................: 0.0.0.0
   Subnet Mask.....................: 0.0.0.0
   Default Gateway.................: ::
                                     0.0.0.0

C:\>
C:\>
C:\>
C:\>ping 192.168.1.1

Pinging 192.168.1.1 with 32 bytes of data:

Reply from 192.168.1.1: bytes=32 time<1ms TTL=255
Reply from 192.168.1.1: bytes=32 time<1ms TTL=255
Reply from 192.168.1.1: bytes=32 time<1ms TTL=255
Reply from 192.168.1.1: bytes=32 time<1ms TTL=255
```

```
R1(config)#no ip domain-lookup
```



ab 2 - Static Route.pkt
Root
20:01:30
192.168.2.0/24
Fa0/0
Fa0/1
192.168.3.0/24
1841
R2
Fa0/1
Fa0/0
1841
R3
Fa0/1
192.168.4.0/24
Fa0/4
Fa0/2
Fa0
Fa0
Fa0
PC-PT
PC6
PC-PT
PC7
PC-PT
PC8
168.1.1
168.1.1
Realtime
Simulation
Scenario 0
New
Delete
Toggle PDU List Window
Fire
Last Status
Source
Destination
Type
Color
Time(sec)
Periodic
teams.microsoft.com is sharing your screen.
Stop sharing
Hide
atically Choose Connection Type

# Lab 2 : Static Route

R1(config)#int fastEthernet 0/1

R1(config-if)#ip add 192.168.2.1 255.255.255.0

R1(config-if)#no shutdown

Verification

#show run

#show ip interface brief

```
Router>en
Router#
Router#conf t
Router(config)#hostname R3
R3(config)#
R3(config)#int fa0/0
R3(config-if)#ip add 192.168.3.2 255.255.255.0
R3(config-if)#no shutdown
R3(config-if)#


R3(config)#int fa0/1

R3(config-if)#ip add 192.168.4.1 255.255.255.0

R3(config-if)#no shutdown



#show run

#show ip int brief
```

#show ip int brief (R1, R2 and R3)

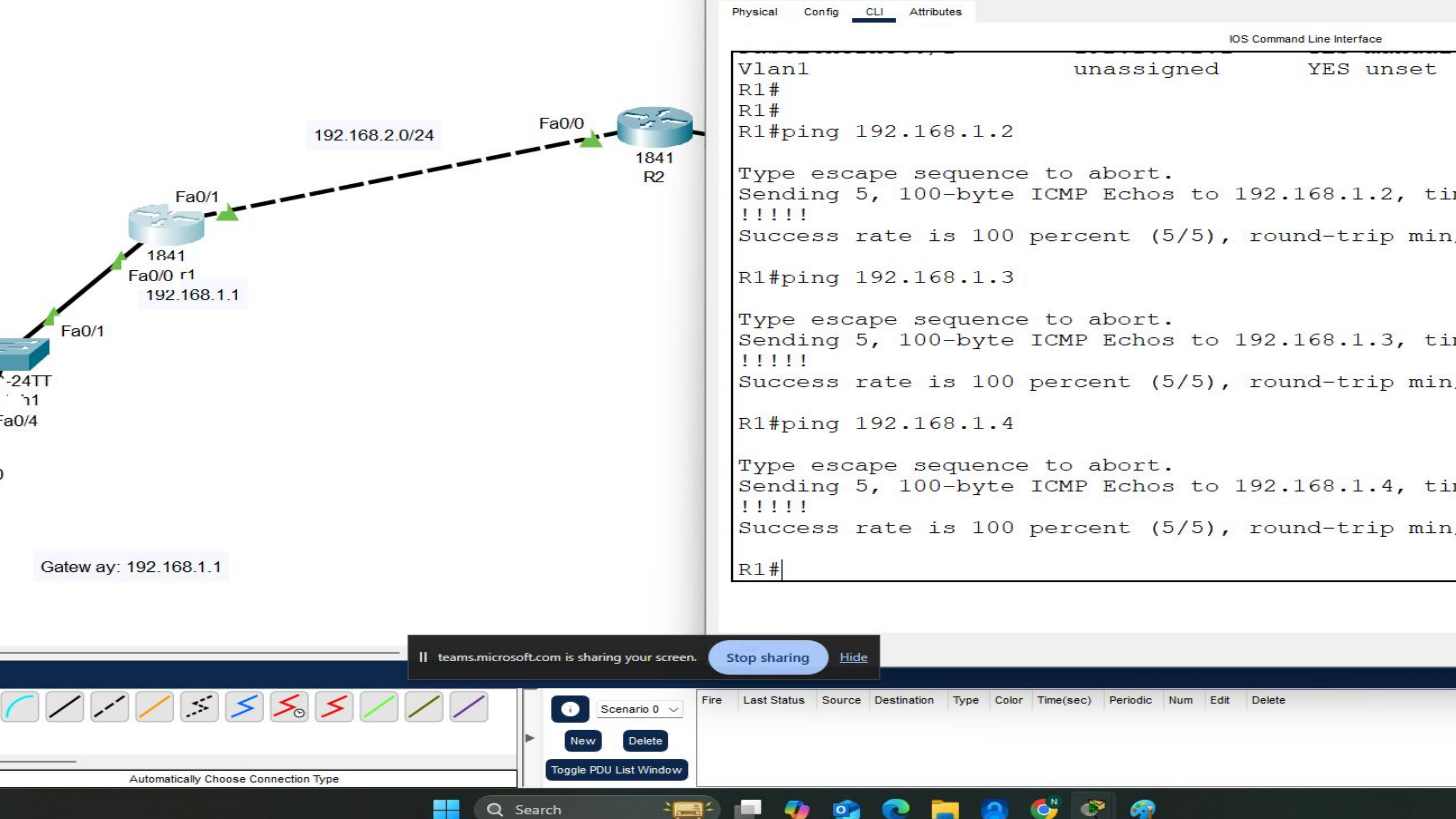
Up up

```
R1#show ip int bri
Interface              IP-Address      OK? Method Status                Protocol
FastEthernet0/0        192.168.1.1     YES manual up                    up
FastEthernet0/1        192.168.2.1     YES manual up                    up
Vlan1                  unassigned      YES unset  administratively down down
R1#
```

Copy Paste

```
R2>
R2>
R2>en
R2#show ip int bri
Interface              IP-Address      OK? Method Status                Protocol
FastEthernet0/0        192.168.2.2     YES manual up                    up
FastEthernet0/1        192.168.3.1     YES manual up                    up
Vlan1                  unassigned      YES unset  administratively down down
R2#
```

```
R3>en
R3#show ip int bri
Interface              IP-Address      OK? Method Status                Protocol
FastEthernet0/0        192.168.3.2     YES manual up                    up
FastEthernet0/1        192.168.4.1     YES manual up                    up
Vlan1                  unassigned      YES unset  administratively down down
R3#
```



Physical
Config
CLI
Attributes
IOS Command Line Interface
Vlan1 unassigned YES unset
R1#
R1#
R1#ping 192.168.1.2
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.1.2, ti
!!!!!
Success rate is 100 percent (5/5), round-trip min
R1#ping 192.168.1.3
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.1.3, ti
!!!!!
Success rate is 100 percent (5/5), round-trip min
R1#ping 192.168.1.4
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.1.4, ti
!!!!!
Success rate is 100 percent (5/5), round-trip min
R1#
192.168.2.0/24
Fa0/0
1841
R2
Fa0/1
1841
Fa0/0 r1
192.168.1.1
Fa0/1
-24TT
Fa0/4
Gatew ay: 192.168.1.1
teams.microsoft.com is sharing your screen.
Stop sharing
Hide
Scenario 0
New
Delete
Toggle PDU List Window
Fire
Last Status
Source
Destination
Type
Color
Time(sec)
Periodic
Num
Edit
Delete
Automatically Choose Connection Type
Search

```
R1#

R1#ping 192.168.2.2

Type escape sequence to abort.

Sending 5, 100-byte ICMP Echos to 192.168.2.2, timeout is 2 seconds:

.!!!!

Success rate is 80 percent (4/5), round-trip min/avg/max = 0/0/1 ms

R1#ping 192.168.3.1

Type escape sequence to abort.

Sending 5, 100-byte ICMP Echos to 192.168.3.1, timeout is 2 seconds:

.....

Success rate is 0 percent (0/5)
```

Static route

*R1(config)#ip route <destination network> <subnet mask> <Next-Hop/Exit Interface>*

*R1(config)#ip route 192.168.3.0 255.255.255.0 192.168.2.2*

*R1(config)#ip route 192.168.4.0 255.255.255.0 192.168.2.2*

*R1(config)#*

```
R2(config)#ip route 192.168.1.0 255.255.255.0 192.168.2.1
R2(config)#ip route 192.168.4.0 255.255.255.0 192.168.3.2
R2(config)#
```

R3(config)#ip route 192.168.1.0 255.255.255.0 192.168.3.1

R3(config)#ip route 192.168.2.0 255.255.255.0 192.168.3.1

Verification

#show run

#show ip route

Ping destination

# Lab 3: Default Route

Removing static route

No ip route 192.168.3.0 255.255.255.0 192.168.2.2
No ip route 192.168.4.0 255.255.255.0 192.168.2.2

R1

Default route.

Ip route 0.0.0.0 0.0.0.0 192.168.2.2

```
R3(config)#ip route 0.0.0.0 0.0.0.0 192.168.3.1
```

# Routing Information Protocol (RIP)

# RIP Versions | Types

- **RIPv1 (IPv4)**
- RIPv2 (IPv4)
- RIPng (for IPv6) —---------Next Generation

RIPv1 is a classful routing protocol (the routing updates will not carry the subnetmask information of the networks)

**10.10.10.0/24 —----------RIPv1 (10.0.0.0/8)**

RIPv2 is a classless routing protocol (the routing updates will carry the subnetmask information of the networks). **10.10.10.0/24** —-> **10.10.10.0/24**

# RIP Features

- RIP sends out periodic routing updates (every 30 seconds)
- RIP sends out the full routing table every periodic update
- RIP’s metric is hop count. (Max: 15 hops) | used in small Networks
- RIP uses the Distance Vector algorithm to determine the best “path” to a particular destination
- RIP supports IPv4, IPv6 and **IPX** routing.
- RIPv1,v2, RIPng uses UDP port 520 for sending/receiving updates
- RIP routes have an administrative distance of 120.
- RIPv1 sends updates to 255.255.255.255 (all broadcast address)
- RIPv2 sends updates to 224.0.0.9 (Reserved Multicast address)

# RIP Timers

### 1. Update Timer

- **Purpose**: This timer determines how often a router sends out its entire routing table (a full update) to its neighbors.
- **Default Value**: 30 seconds
- **Description**: Every 30 seconds, a router will send an update message to its neighbors containing the current state of its routing table. This ensures that the network topology is kept up to date across all routers.

### 2. Invalid Timer

- **Purpose**: This timer indicates how long a router will retain a route before considering it invalid if no update is received for that route.
- **Default Value**: 180 seconds (3 minutes)
- **Description**: If a router doesn't receive an update for a specific route within 180 seconds, it will mark that route as "invalid." The router will stop using the invalid route and will initiate the process of finding an alternative route.

### 3. Hold-down Timer

- **Purpose**: This timer is used to prevent flapping (rapid changes) of routes and to stabilize the network.
- **Default Value**: 180 seconds (3 minutes)
- **Description**: When a route becomes invalid, the hold-down timer is started. During the hold-down period, the router will not accept any new routing information that could change the state of the invalid route. This helps prevent incorrect routing information from spreading if the network is experiencing instability.

### 4. Flush Timer

- **Purpose**: This timer controls how long a router will keep a route in its routing table after it has been invalidated and marked as unreachable.
- **Default Value**: 240 seconds (4 minutes)
- **Description**: If a route is not restored within the flush timer period, it is completely removed from the routing table. This ensures that the router's routing table does not hold onto old or outdated routes indefinitely.

```
R1> enable
R1# configure terminal
R1(config)# router rip
R1(config-router)# version 2
R1(config-router)# no auto-summary
R1(config-router)# network 192.168.1.0
R1(config-router)# network 192.168.2.0
```

# Sample RIPv2 Configuration (please remove static/default route)

**R1(config)#no ip route <>**

R1(config)#router rip
R1(config-router)#version 2
R1(config-router)#network 192.168.1.0
R1(config-router)#network 192.168.2.0
R1(config-router)#

R2(config)#router rip
R2(config-router)#version 2
R2(config-router)#network 192.168.2.0
R2(config-router)#network 192.168.3.0
R2(config-router)#

```
R3(config)#router rip
R3(config-router)#version 2
R3(config-router)#network 192.168.3.0
R3(config-router)#network 192.168.4.0
R3(config-router)#
```

Verification

```
Rx#show run
Rx#show ip protocols
Rx#show ip route
Rx#show ip route rip
Rx#show ip rip database
```

Lab 4: RIPv2 Timers

```
R1(config)#router rip
R1(config-router)#timers basic 10 60 60 80
```

# Verification Commands

#show ip route

#show ip route rip

#show ip protocols

#show run

# Remove RIP, Static, Default Route

Removing RIP

**Rx(config)#no router rip**

#show ip protocols

#show run

Removing Static or Default route

Show run

Copy paste the static route.

**(config)#no <command which you have copied from show run>**

# Enhanced Interior Gateway Routing Protocol (EIGRP)

# EIGRP Features

- Enhanced IGRP **used to be Cisco-proprietary routing protocol**, now updated as Open Standard in IETF
- EIGRP was created as a classless routing protocol (will carry subnet mask information with the routing updates)
- EIGRP acts like a link-state routing protocol, but it’s still a distance vector routing protocol (Dual/Hybrid Routing Protocol)
- AD value of 90 (Internal EIGRP) & 170 (External EIGRP)
- EIGRP is used in Enterprise and Campus Network

## Features of EIGRP

1. **Fast Convergence**: EIGRP converges quickly after network topology changes, ensuring minimal downtime.
2. **Reliable Transport Protocol (RTP)**: EIGRP uses RTP to reliably deliver updates between routers.
3. **Support for Multiple Network Layer Protocols**: EIGRP can support IPv4, IPv6, AppleTalk, and IPX, although it is most commonly used with IPv4 and IPv6.
4. **DUAL (Diffusing Update Algorithm)**: The DUAL algorithm allows EIGRP to select the best route while ensuring that alternative backup routes are available in case the primary route fails.
5. **Partial Updates**: Unlike traditional distance vector protocols (e.g., RIP), EIGRP sends only partial updates when a topology change occurs, reducing network bandwidth usage. EIGRP updates are partial, bounded, non periodic

R1 —---------------------------------------------------------------------------R2

191.168.1.0/24 , 192.168.2.0/24, 10.10.0.0/16

172.16.0.0/16

Metric K1, K2, K3, K4, K5 (by default **K1 & K3 = 1**, K2 = K4 = K5 = 0)

**K1 - Bandwidth (Higher is preferred)**

K2 - Reliability

**K3 - Delay (Lower is preferred)**

K4 - Load

K5 - MTU (Maximum Transmission Unit)

## EIGRP Tables

- **Neighbor Table**: Contains a list of (Directly connected) neighbors and their status.
- **Topology Table**: Contains all known routes to a destination and the metrics associated with those routes.
- **Routing Table: Contains the best routes to each destination, selected from the topology table.**

## EIGRP Packet Types

1. **Hello Packet**: Used to discover and maintain neighbor relationships.
2. **Update Packet**: Used to send routing updates and exchange routing information between neighbors.
3. **Query Packet**: Sent when a router needs more information to determine a route.
4. **Reply Packet**: Sent in response to a query packet, providing the requested routing information.
5. **Acknowledge Packet**: Used to confirm receipt of update and query packets.

## EIGRP Timers

EIGRP uses the following timers:

1. **Hello Timer**: Defines how often the router sends Hello packets to maintain neighbor relationships (default 5 seconds).
2. **Hold Timer**: Determines how long a router will wait for a Hello packet from a neighbor before declaring the neighbor down (default 15 seconds).

## How EIGRP Works

### 1. Hello Protocol

- EIGRP routers use **Hello packets** to discover and maintain neighbor relationships with other EIGRP-enabled routers.
- Hello packets are multicast at a regular interval (typically every 5 seconds) to establish and maintain a neighbor relationship.

### 2. Neighbor Table

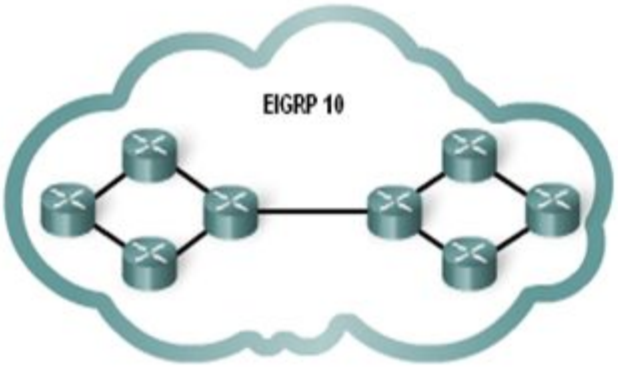
- EIGRP routers maintain a **Neighbor Table** which stores information about the routers they are directly connected to (neighbors). This table includes information such as the router's IP address and the status of the relationship (up or down).

**_router eigrp_ command**

***R1(router)#router eigrp autonomous-system***

All routers in the EIGRP routing domain must use the sam process ID number (autonomous-system number)

Single Process IDs




```
R1(config)#router eigrp ?
  <1-65535>   Autonomous system number
R1(config)#router eigrp 10
```

Although the Cisco IOS refers to the router eigrp parameter as an "Autonomous system number", thi parameter configures an EIGRP process-an instance of EIGRP running on the router-and has nothing

## R1

```
router eigrp 100
no auto-summary
network 192.168.1.0
network 192.168.2.0
```

## R2

```
router eigrp 100
no auto-summary
network 192.168.2.0
network 192.168.3.0
```

## R3

```
router eigrp 100
no auto-summary
network 192.168.3.0
network 192.168.4.0
```

# EIGRP Verifications

*#show run*

*#show ip protocols*

*#show ip route*

***#show ip route eigrp*** ***(Routing Table)***

***#show ip eigrp neighbor*** ***(Neighbor Table)***

***#show ip eigrp topology*** ***(Topology Table)***

# Removing EIGRP

no router eigrp 100

# Open Shortest Path First (OSPF)

# Link State Routing Protocol

- A **Link-State Routing Protocol** builds a complete map of the network by exchanging information about the **state of links** (interfaces) between routers.
- Each router independently calculates the **shortest path** to all destinations using an algorithm like **Dijkstra's**.

# How Link-State Works (Simplified Flow):

- **Each router** discovers its neighbors and their link states.
- Routers create **Link-State Advertisements (LSAs)**.
- LSAs are **flooded** throughout the area.
- Each router **builds a topology database** (LSDB).
- The router runs **SPF (Dijkstra)** to calculate the **shortest path tree**.
- The output becomes the **routing table**.

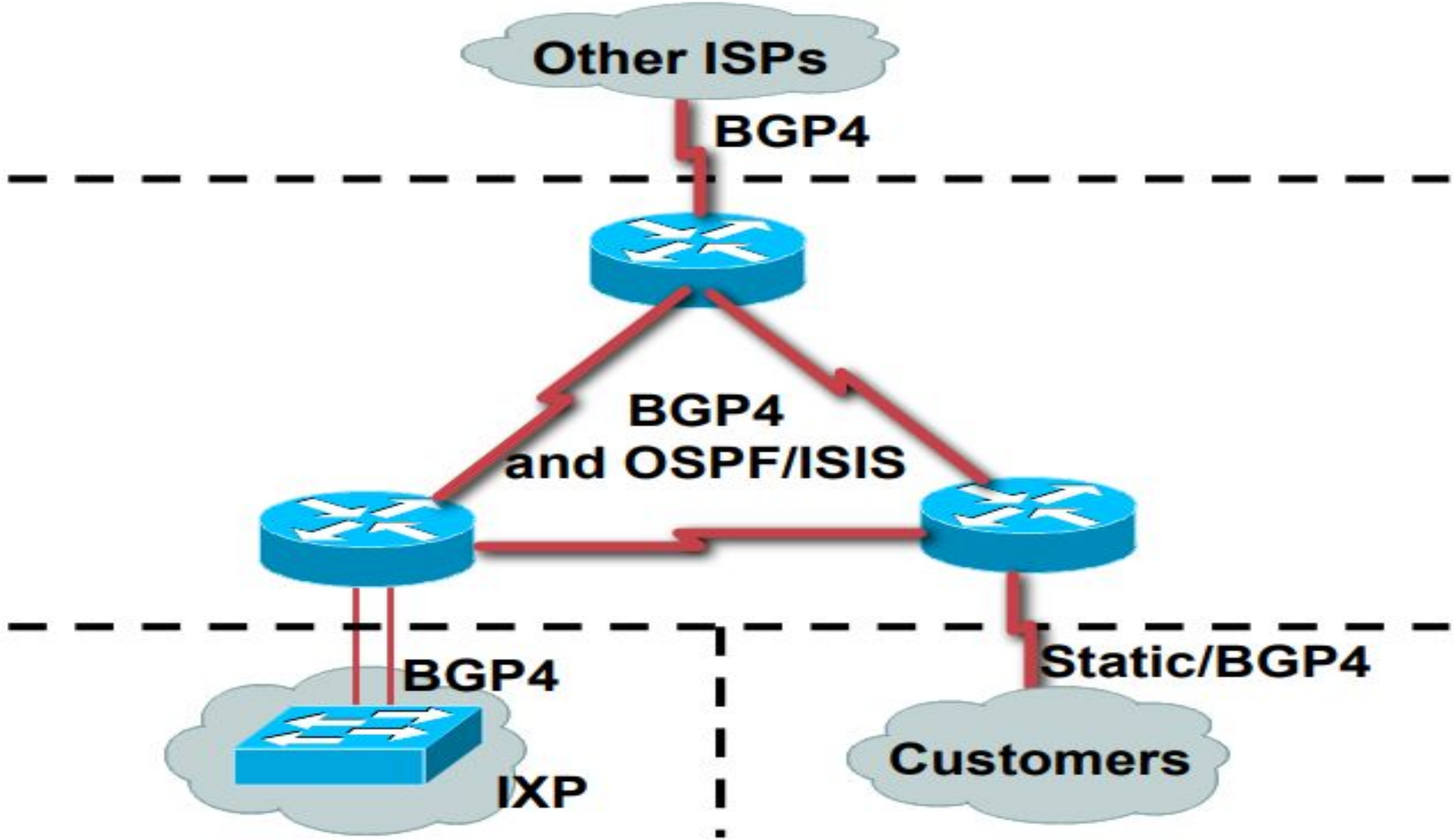
# IGP v/s EGP

## Interior Gateway Protocol (IGP)

- Carries ISP infrastructure addresses only ISPs aim to keep the IGP small for efficiency and scalability.  Eg. OSPF, ISIS

## Exterior Gateway Protocol (EGP)

- Carries customer prefixes
- Carries Internet prefixes
- EGPs are independent of ISP network topology

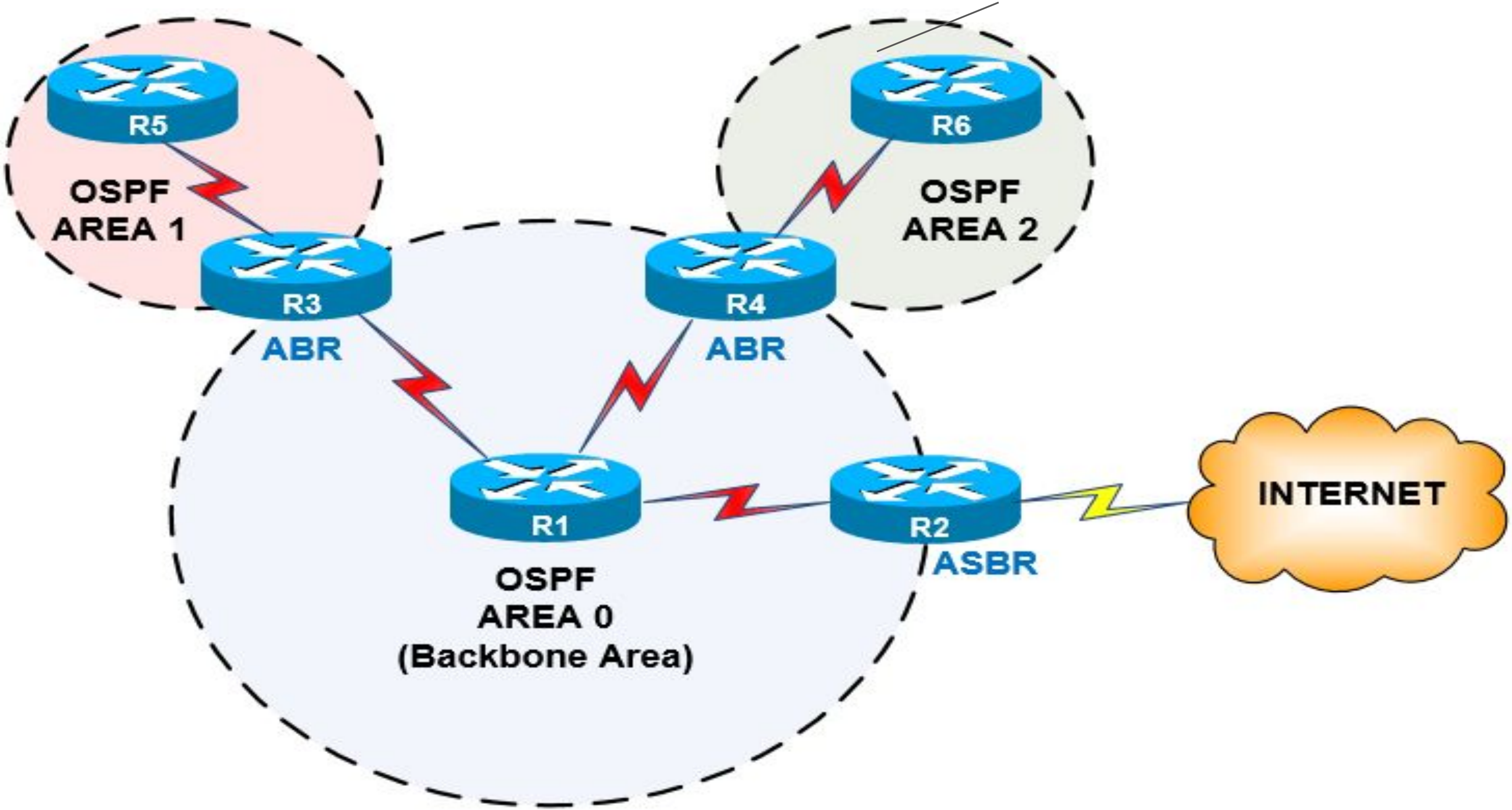

Other ISPs
BGP4
BGP4
and OSPF/ISIS
BGP4
IXP
Static/BGP4
Customers

- OSPF is a link state routing protocol, which is used in Large Enterprise Networks & Service Providers environment.
- OSPF deploys a hierarchical network design using Areas.
- OSPF uses Dijkstra's SPF algorithm to calculate the best path
- OSPF will form  neighborship with routers which belong to one area.
- OSPF advertises the state of the links as the Link State Advertisements (LSA)
- LSAs are send periodically every 30 minutes
- OSPF has an Administrative Distance (AD) value of 110
- OSPF uses Cost as the metric for calculating the best path.

  10^8 / Bandwidth = Cost

# OSPFv2/OSPFv3

- OSPFv2 is used for carrying IPv4 routes
- OSPFv3 is used for carrying IPv4/IPv6 routes


R5
OSPF
AREA 1
R3
ABR
R6
OSPF
AREA 2
R4
ABR
R1
R2
ASBR
INTERNET
OSPF
AREA 0
(Backbone Area)

- OSPF traffic is multicast either to address 224.0.0.5 (all OSPF routers) or 224.0.0.6 (all Designated Routers).
- OSPF is a classless protocol, and thus supports VLSMs.

Other characteristics of OSPF include:

- OSPF supports only IP routing.
- OSPF routes have an administrative distance is 110.
- OSPF uses cost as its metric, which is computed based on the bandwidth of the link.
- OSPF has no hop-count limit.
- OSPF is a Layer 3 routing protocol (Protocol number 89)

EIGRP/OSPF area layer 3 protocols, RIPv2 is application layer protocol *uses UDP for sending/receiving packets/updates.

four separate OSPF router types are as follows:

- Internal Routers – all router interfaces belong to only one Area.
- Area Border Routers (ABRs) – contains interfaces in at least two separate areas
- Backbone Routers – contain at least one interface in Area 0
- Autonomous System Border Routers (ASBRs) – contain a connection to a separate Autonomous System

# LSA

- **Router LSA (Type 1) –** Contains a list of all links local to the router, and the status and “cost” of those links. Type 1 LSAs are generated by all routers in OSPF, and are flooded to all other routers within the local area.

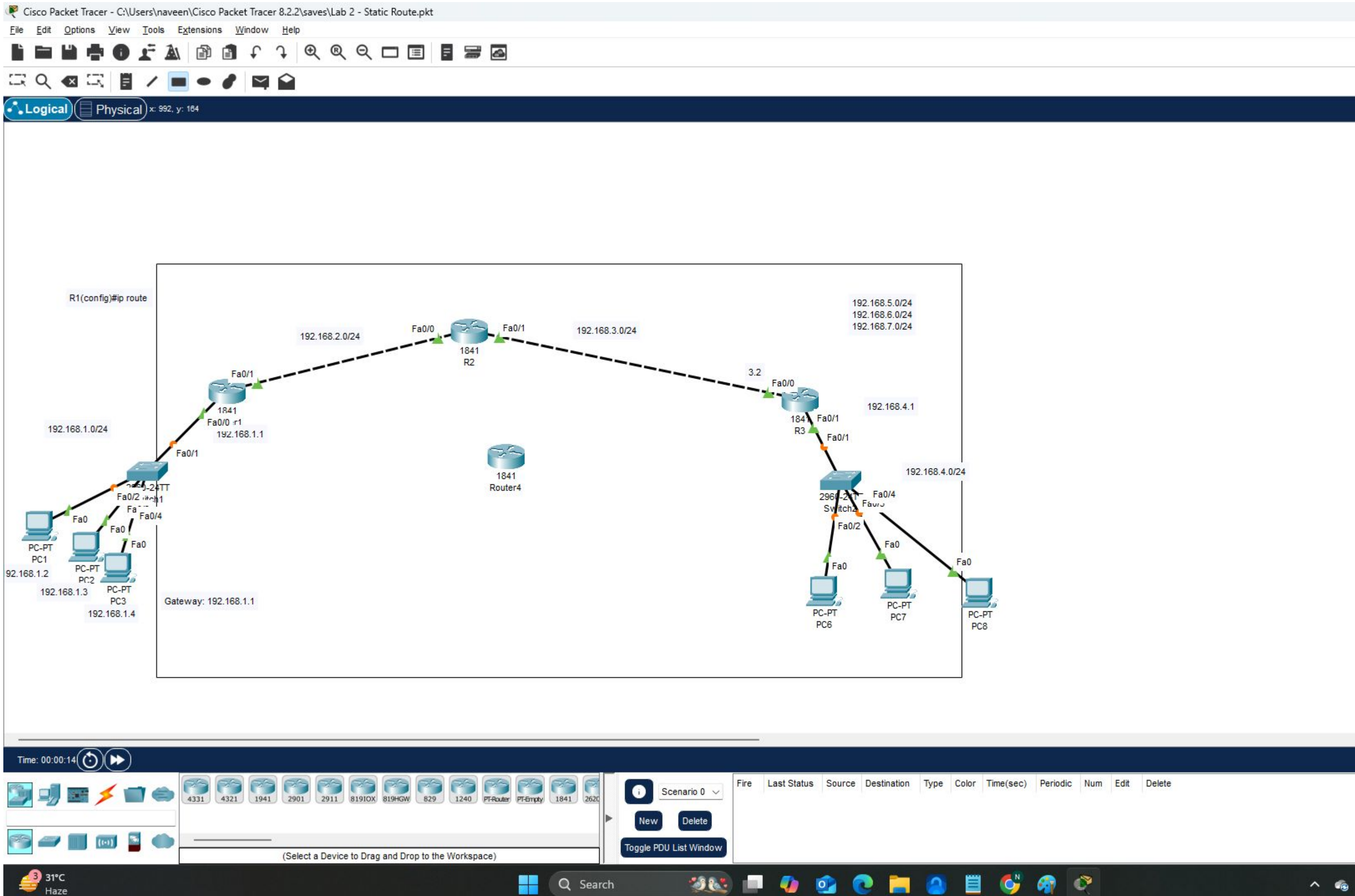
- **Network LSA (Type 2) –** Generated by all Designated Routers in OSPF, and contains a list of all routers attached to the Designated Router.

- **Network Summary LSA (Type 3) –** Generated by all ABRs in OSPF, and contains a list of all destination networks within an area. Type 3 LSAs are sent between areas to allow inter-area communication to occur.

**ASBR Summary LSA (Type 4) –** Generated by ABRs in OSPF, and contains a route to any ASBRs in the OSPF system. Type 4 LSAs are sent from an ABR into its local area, so that Internal routers know how to exit the Autonomous System.

**External LSA (Type 5) –** Generated by ASBRs in OSPF, and contain routes to destination networks outside the local Autonomous System. Type 5 LSAs can also take the form of a default route to all networks outside the local AS. Type 5 LSAs are flooded to all areas in the OSPF system.

**Type 6 LSA (MOSF) Multicast OSPF** - Cisco Routers doesn't support this LSA.


Cisco Packet Tracer - C:\Users\naveen\Cisco Packet Tracer 8.2.2\saves\Lab 2 - Static Route.pkt
File Edit Options View Tools Extensions Window Help
Logical
Physical
x: 992, y: 164
R1(config)#ip route
192.168.2.0/24
Fa0/0
1841
R2
Fa0/1
192.168.3.0/24
192.168.5.0/24
192.168.6.0/24
192.168.7.0/24
Fa0/1
3.2
Fa0/0
192.168.4.1
Fa0/0
192.168.1.1
192.168.1.0/24
Fa0/1
1841
Router4
Fa0/1
R3
Fa0/1
192.168.4.0/24
Fa0/2
Fa0/4
Fa0
PC-PT
PC1
Fa0
PC-PT
PC3
192.168.1.3
192.168.1.4
Gateway: 192.168.1.1
Fa0/4
Fa0/2
Fa0
PC-PT
PC6
PC-PT
PC7
PC-PT
PC8
Time: 00:00:14
4331
4321
1941
2901
2911
819IOX
819HGW
829
1240
PT-Router
PT-Empty
1841
Scenario 0
New
Delete
Toggle PDU List Window
Fire
Last Status
Source
Destination
Type
Color
Time(sec)
Periodic
Num
Edit
Delete
(Select a Device to Drag and Drop to the Workspace)
31°C
Haze
Search

# OSPF Single Area

R1

Router ospf 1

Router-id 1.1.1.1

Network 192.168.1.0 0.0.0.255 area 0

Network 192.168.2.0 0.0.0.255 area 0

R2

Router ospf 1

Router-id 2.2.2.2

Network 192.168.2.0 0.0.0.255 area 0

Network 192.168.3.0 0.0.0.255 area 0

R3

Router ospf 1

Router-id 3.3.3.3

Network 192.168.4.0 0.0.0.255 area 0

Network 192.168.3.0 0.0.0.255 area 0

#show run

#show ip protocols

#show ip ospf neighbor (Neighbor Table)

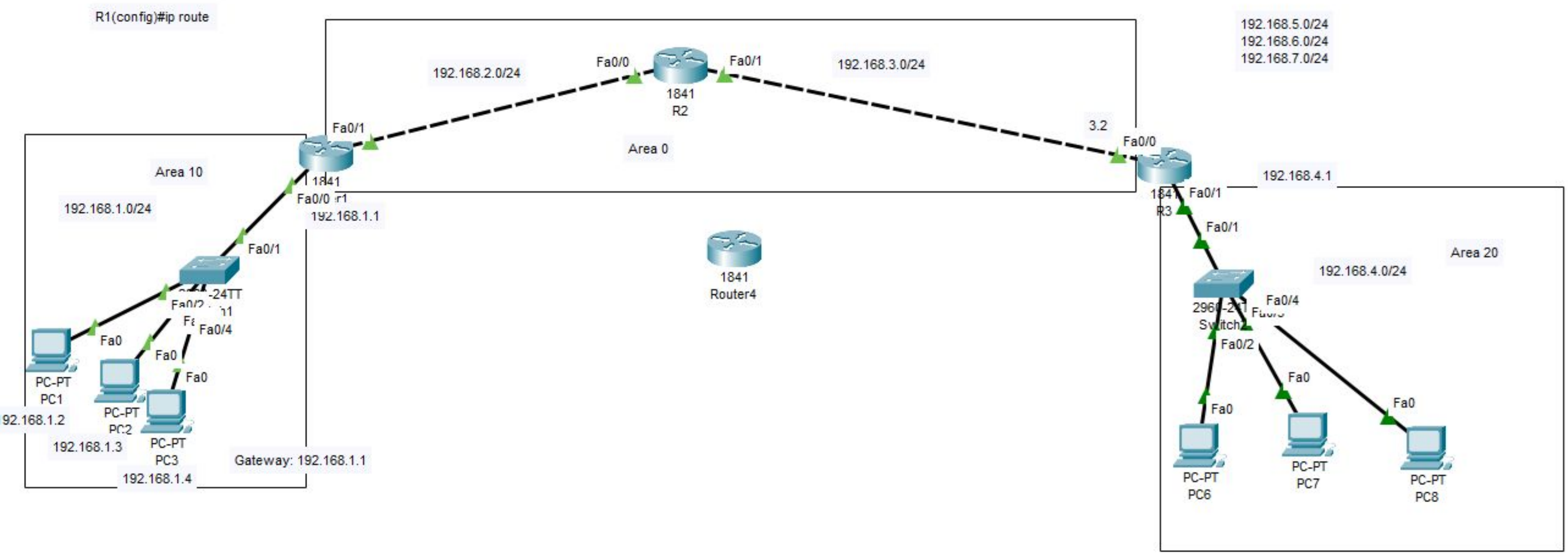
#show ip route (Routing table)

#show ip route ospf

#show ip ospf database (Topology Table)

R2#clear ip ospf process
Reset ALL OSPF processes? [no]: yes
#show ip ospf interface fast0/1 Cosf of fastethernet - 1, Serial/WAN - 64

# OSPF Multi Area



# OSPF Multi Area

R1

Router ospf 1

Network 192.168.1.0 0.0.0.255 area 10

Network 192.168.2.0 0.0.0.255 area 0

R2

Router ospf 1

Network 192.168.2.0 0.0.0.255 area 0

Network 192.168.3.0 0.0.0.255 area 0

R3

Router ospf 1

Network 192.168.4.0 0.0.0.255 area 20

Network 192.168.3.0 0.0.0.255 area 0

The **Gateway of Last Resort** (often referred to as the **default gateway**) is the router or network device that a router uses when it cannot find a route to a destination in its routing table. Essentially, it's the "catch-all" route for any traffic that doesn't match a more specific route in the routing table.

## Why is the Gateway of Last Resort Important?

- **Default Route**: It is essentially the default route, used when the router has no other specific route to a destination.
- **Routing Table Fallback**: When a router does not have a specific entry for a destination in its routing table, it sends the packet to the **Gateway of Last Resort**. This helps ensure that packets can still reach remote destinations, even if no detailed route exists for them.

**How the Gateway of Last Resort Works:**

1. If a router receives a packet destined for an IP address that is not in its routing table, it will forward the packet to the **Gateway of Last Resort**.
2. The **Gateway of Last Resort** is typically configured as a static route to a router that is capable of forwarding packets to their final destination, such as an Internet router or another network gateway.
3. The **Gateway of Last Resort** helps provide connectivity to destinations outside the router's local network, especially in the case of routing protocols like **RIP**, **OSPF**, and **EIGRP**, where the router may not know every possible destination in the network.

**Example of configuring a Gateway of Last Resort:**

In Cisco devices, you can configure a default route (Gateway of Last Resort) using the following commands:

**1. To configure a static default route (Gateway of Last Resort):**

**Router(config)# ip route 0.0.0.0 0.0.0.0 192.168.1.1**