ROUTER

- Its a networking device to allow communication between 2 or more NETWORKS.
- Types of routers:

    1. Branch router

        – used for small org.

        – series: 800, 1800, 2800, 2900..

    2. Internet-edge router

        – used by mid-level orgs.

        – series: 1000, 7000, 7500, 7560, 7600…

    3. Service provide router

        – used by WAN or big/huge orgs. like ISPs.

        – series: 900, 1000, 7200, 7300, 7600…

ROUTER COMPONENTS

- The basic components of any Cisco router are :
  - Interfaces – for accessing routers
  - The Processor (CPU) – used for connecting with other device.
  - Internetwork Operating System (IOS) – it the Operating system (current: *Cisco IOS 15.9*)
  - RXBoot Image – aka boot loader, used when IOS is not in use (for maintenance purpose)
  - RAM - 32 to 64 MB
  - NVRAM - router holds its configuration
  - ROM – read-only memory that stores code like Bootstrap & POST.
  - Flash memory – it stores the router's operating system (IOS)
  - Configuration Register – determines if the router is going to boot the IOS image from its Flash, tftp server or just load the RXBoot image.

ROUTING

- It is a process of selecting path/route along which the data can be transferred from source to destination.
- Routing is done with the help of router.
- Routing works on "network layer" of OSI model.
- Routing works on "internet layer" of TCP/IP model.
- Routing Algo. are used for routing the packets
  - Routing algorithm is responsible for deciding the optimal path.
- Types of Routing:

1. Static routing
2. Default routing
3. Dynamic routing

TYPES OF ROUTING – **STATIC ROUTING**

- Aka Non-Adaptive Routing.
- In this, administrator manually enters/adds routes in the routing table.
- Advantage:
    - No overhead – no CPU usage, cheap.
    - No bandwidth – usage between routers.
- Disadvantage:
    - Difficult for large networks.
    - Admins must have in-depth knowledge on the topology, as each route is added manually.

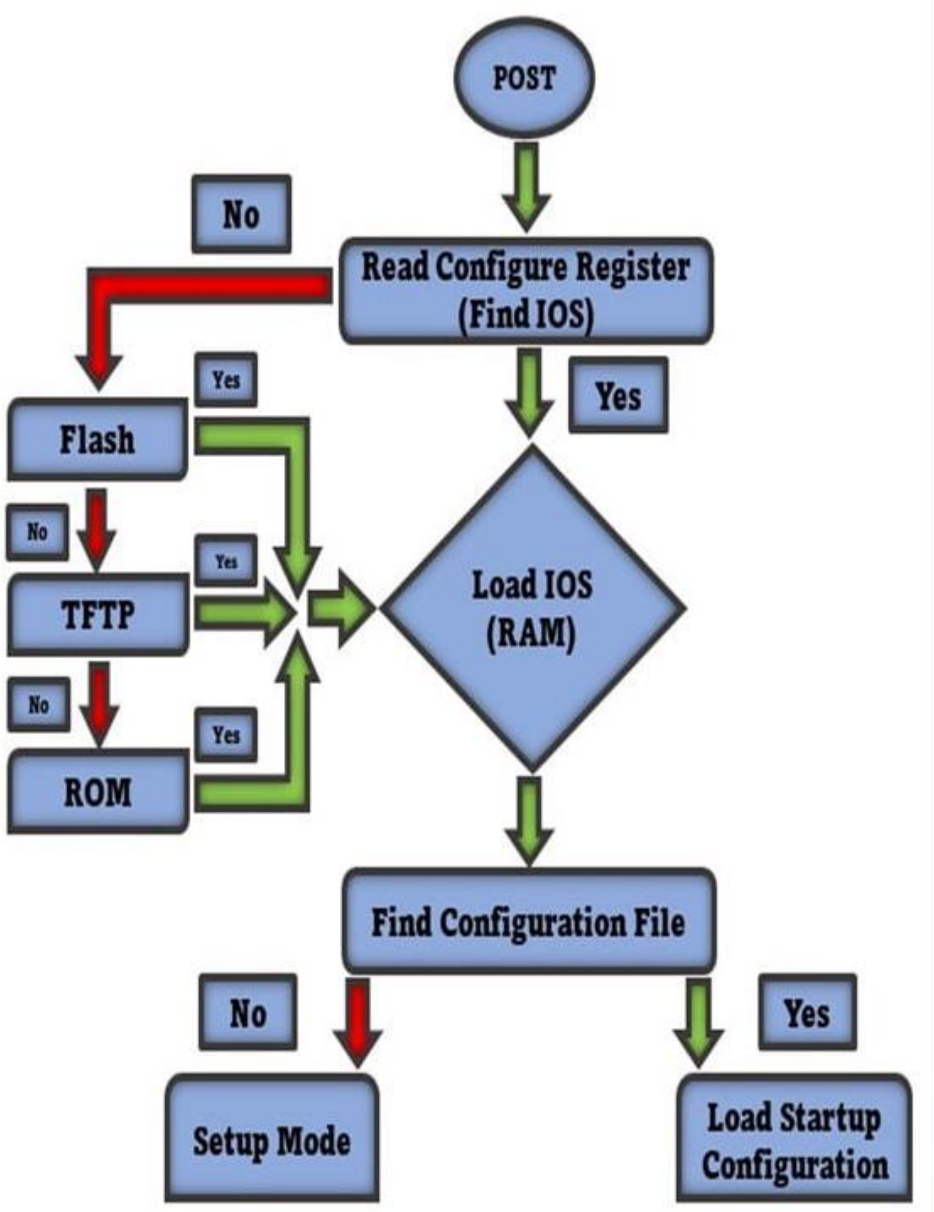
TYPES OF ROUTING – **DEFAULT ROUTING**

- It's a technique in which a router is configured to sent all the packets to the same hop device.
- It doesn't matter whether if belongs to a particular network or net.
- A PKT is transmitted to the device for which it is configured in default routing.
- Default routing is used when networks deal with the single exit point.

TYPES OF ROUTING – **DYNAMIC ROUTING**

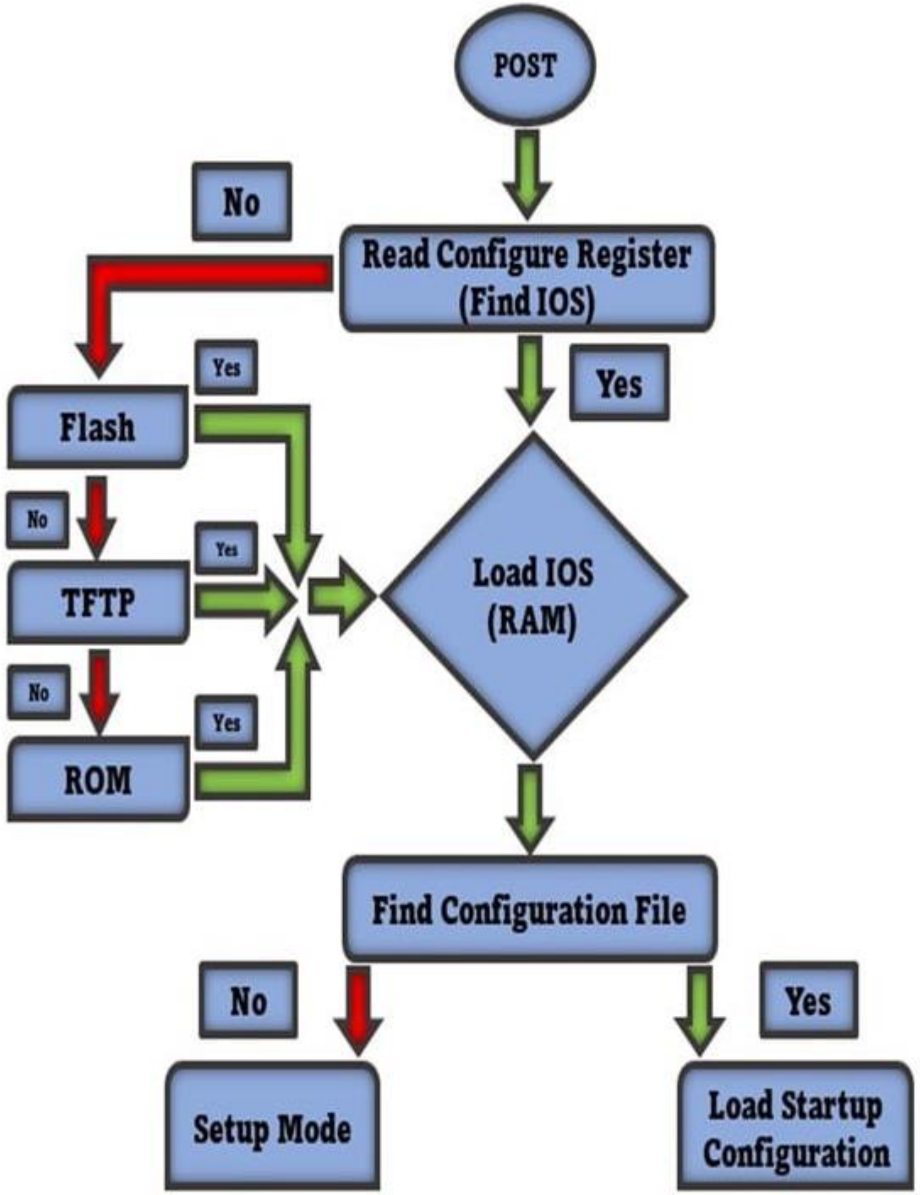
- AKA adaptive Routing
- Here, router adds a new route response to the changes in the condition or topology of network.
- Dynamic protocols are used to discover the new routes to reach the destination.
  - Protocols like RIP & OSPF
- Advantages:
  - Easier to configure.
- Disadvantage:
  - More expensive. Less secure than default & static routing.

THE ROUTER BOOT SEQUENCE



THE ROUTER BOOT SEQUENCE

1. Router is powered on.
2. It performs POST (power on self-test).
3. Bootstrap program is loaded & executed (whenever IOS is found, load it)
4. Bootstrap reads configuration register values & loads the IOS.
5. If bootstrap fails, it will drop boot sequence & then move it to the ROMMON troubleshooting program.
6. If the IOS is loaded, it will try to load the config file.
7. Once the configuration is loaded then CLI interface will be present in front of you.



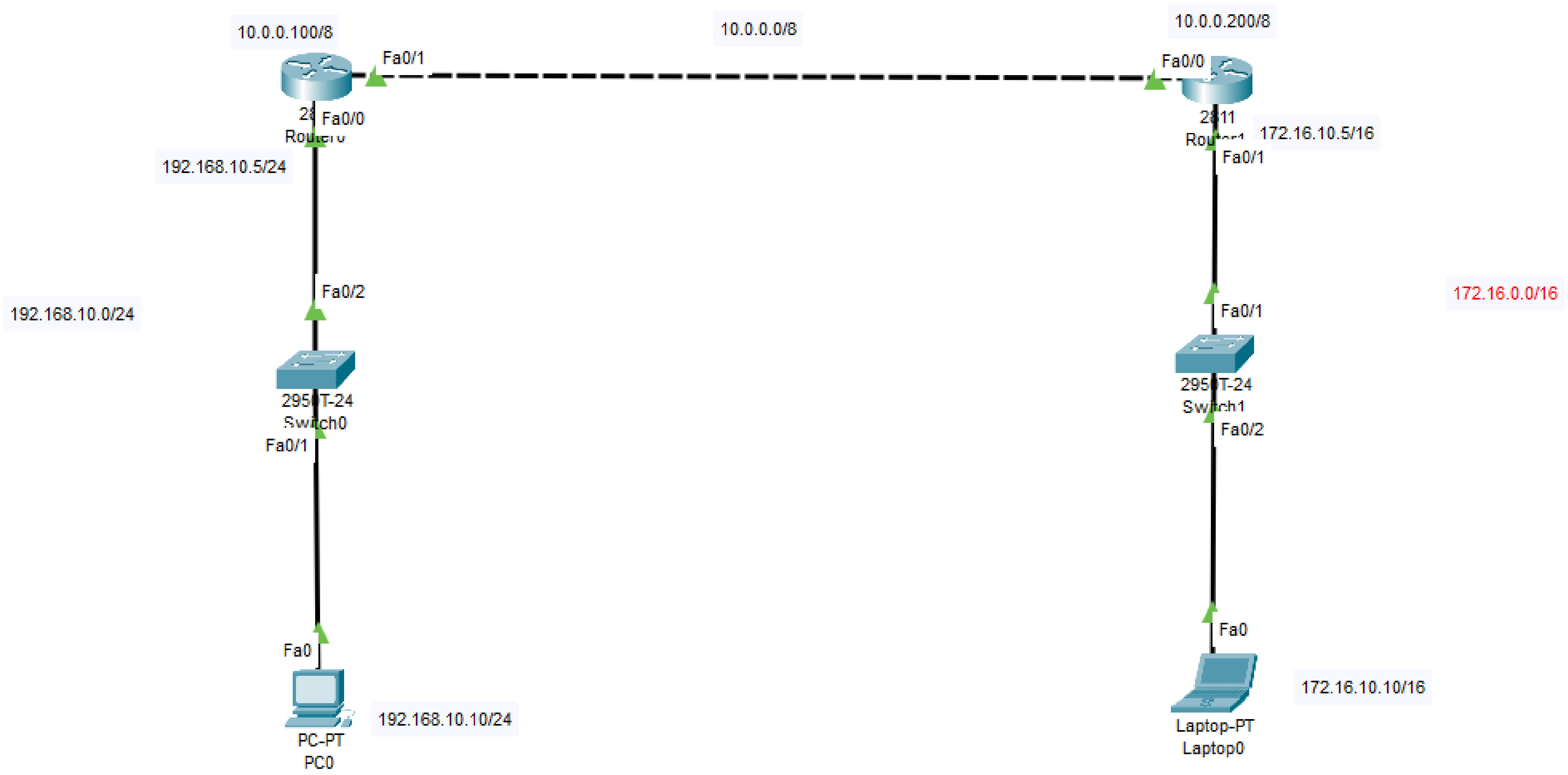
TYPES OF INTERFACES

- Ethernet – physical interface, operates at 10Mbps (IEEE 802.3).
- Fast Ethernet – physical interface, operates at 100Mbps (IEEE 802.3u).
- Gigabit Ethernet – operates at 1000 Mbps (IEEE 802.3ab)
- Serial – used for WAN connections from ISP.
- FDDI – Fiber Distributed Data Interface, 100 Mbps, uses token-passing mech to prevent collisions.
- Token Ring – can operate at either 4 Mbps or 16 Mbps

CISCO DISCOVERY PROTOCOL (CDP)

- CDP is a network discovery tool, which assists network administrators and engineers in identifying neighboring Cisco devices, particularly those running lower-layer (data link layer), transparent protocols.
- It is used to share information about other directly connected Cisco equipment, such as the operating system version and IP address.
- CDP is a Cisco proprietary protocol that is used for collecting directly connected neighbor device information like hardware, software, device name details

STATIC ROUTING



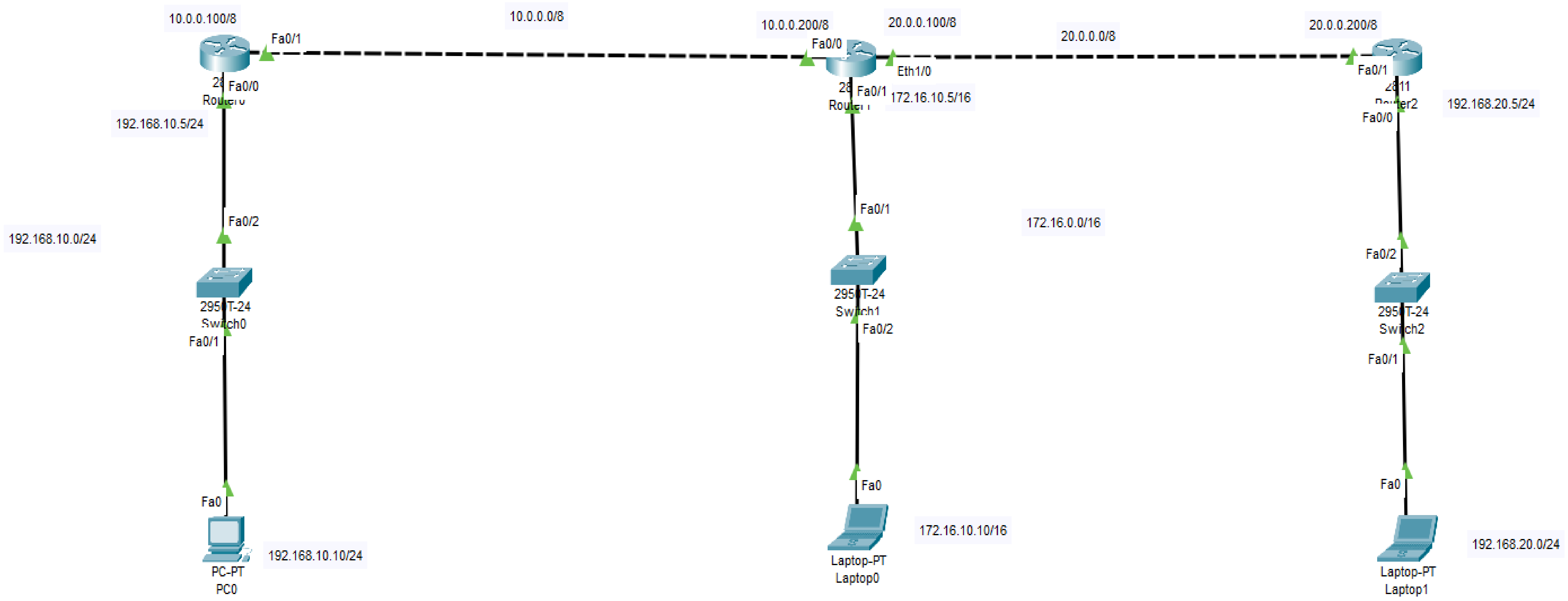
STATIC ROUTING – STEPS

- Add PCs to the environment with IP, subnet & gateway.
- Connect the PC with the switch.
- Connect switch with the router (R1) with default gateway IP address.
- Connect other interface with other network using different IP.
- Enable IP route (via command)
  - Syntax: ip route <network id> <subnet mask><next hop>
    - Router(config)#ip route 172.16.0.0 255.255.0.0 10.0.0.200

TO LIST ROUTING TABLE

```
Router#show 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 not set

     10.0.0.0/8 is variably subnetted, 2 subnets, 2 masks
C       10.0.0.0/8 is directly connected, FastEthernet0/1
L       10.0.0.100/32 is directly connected, FastEthernet0/1
     192.168.10.0/24 is variably subnetted, 2 subnets, 2 masks
C       192.168.10.0/24 is directly connected, FastEthernet0/0
L       192.168.10.5/32 is directly connected, FastEthernet0/0
```

TRYING WITH 3 ROUTERS



R1 ROUTE CONFIG

```
R1#show 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 not set

     10.0.0.0/8 is variably subnetted, 2 subnets, 2 masks
C       10.0.0.0/8 is directly connected, FastEthernet0/1
L       10.0.0.100/32 is directly connected, FastEthernet0/1
S    20.0.0.0/8 [1/0] via 10.0.0.200
S    172.16.0.0/16 [1/0] via 10.0.0.200
     192.168.10.0/24 is variably subnetted, 2 subnets, 2 masks
C       192.168.10.0/24 is directly connected, FastEthernet0/0
L       192.168.10.5/32 is directly connected, FastEthernet0/0
S    192.168.20.0/24 [1/0] via 10.0.0.200
```

R2 ROUTE CONFIG

```
R2#show 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 not set

     10.0.0.0/8 is variably subnetted, 2 subnets, 2 masks
C       10.0.0.0/8 is directly connected, FastEthernet0/0
L       10.0.0.200/32 is directly connected, FastEthernet0/0
     20.0.0.0/8 is variably subnetted, 3 subnets, 3 masks
S       20.0.0.0/8 [1/0] via 20.0.0.200
C       20.0.0.0/24 is directly connected, Ethernet1/0
L       20.0.0.100/32 is directly connected, Ethernet1/0
     172.16.0.0/16 is variably subnetted, 2 subnets, 2 masks
C       172.16.0.0/16 is directly connected, FastEthernet0/1
L       172.16.10.5/32 is directly connected, FastEthernet0/1
S    192.168.10.0/24 [1/0] via 10.0.0.100
S    192.168.20.0/24 [1/0] via 20.0.0.200
```

R3 ROUTE CONFIG

```
R3#show 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 not set

     10.0.0.0/24 is subnetted, 1 subnets
S       10.0.0.0/24 [1/0] via 20.0.0.100
     20.0.0.0/8 is variably subnetted, 2 subnets, 2 masks
C       20.0.0.0/8 is directly connected, FastEthernet0/1
L       20.0.0.200/32 is directly connected, FastEthernet0/1
S    172.16.0.0/16 [1/0] via 20.0.0.100
S    192.168.10.0/24 [1/0] via 20.0.0.100
     192.168.20.0/24 is variably subnetted, 2 subnets, 2 masks
C       192.168.20.0/24 is directly connected, FastEthernet0/0
L       192.168.20.5/32 is directly connected, FastEthernet0/0
```

ROUTING TERMINOLOGIES

- Administrative Distance
- Metric
- Hop
- Bandwidth & Delay
- Load & Reliability

ROUTING TERMINOLOGIES

- Administrative Distance
  - A numerical value that represents the trustworthiness of a routing source or protocol.
  - Lower AD values are preferred over higher ones.
  - Example: Directly connected routes have an AD of 0, while RIP has an AD of 120.
- Metric
  - A value used by routing protocols to determine the best path to a destination.
  - Metrics can be based on factors like hop count, bandwidth, delay, cost, or reliability.
  - Example: RIP uses hop count, while OSPF uses cost (bandwidth-based).
- Hop
  - Represents the number of routers a packet must pass through to reach its destination.
  - Each router a packet traverses counts as 1 hop.

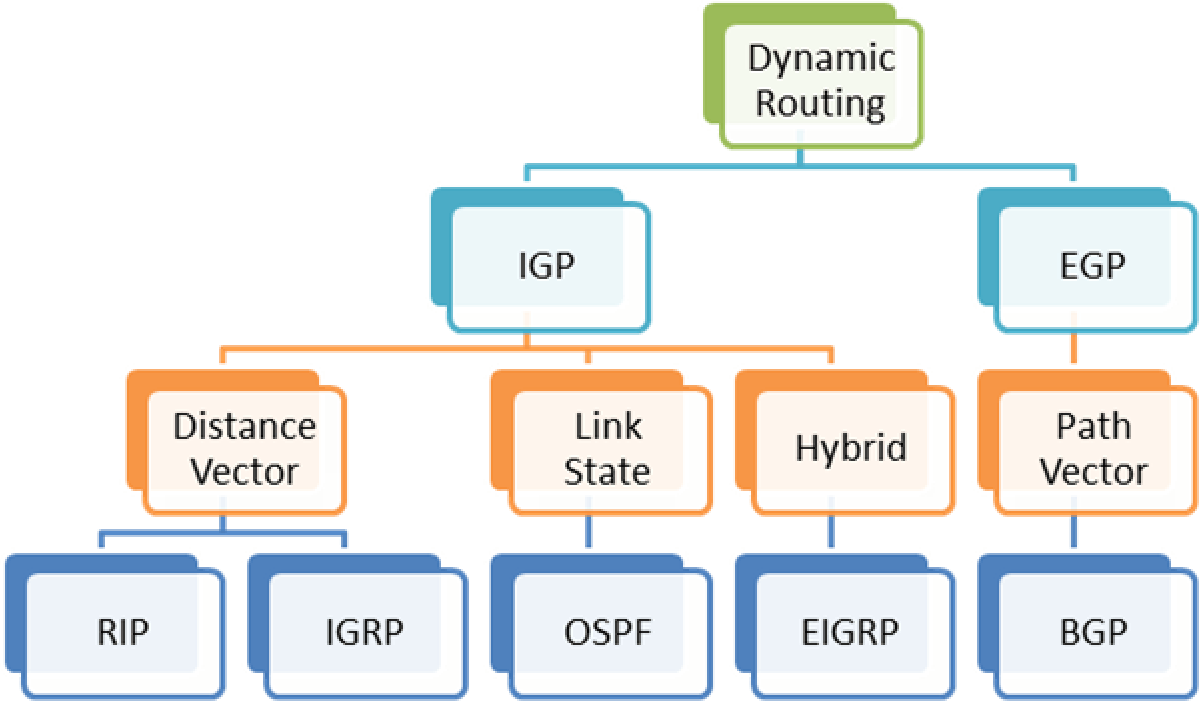
ROUTING TERMINOLOGIES

- Bandwidth & Delay
  - Bandwidth: Refers to the data-carrying capacity of a link, measured in bits per second (bps).
    - Higher bandwidth = preferred path.
  - Delay: Represents the time it takes for a packet to traverse a link.
    - Lower delay = better path.
  - Example: EIGRP uses both bandwidth and delay to calculate its metric.
- Load & Reliability
  - Load: Represents the current utilization of a link or resource, indicating how busy the path is.
    - Lower load = better path.
  - Reliability: Measures the stability of a link, based on historical data (e.g., error rates).
    - Higher reliability = better path.
  - Example: EIGRP considers both load and reliability in its metric calculation.

DYNAMIC ROUTING

Dynamic routing is the process where routers automatically discover and adapt network paths to optimize data transmission.

Unlike static routing, where paths are manually configured, dynamic routing allows for flexibility and adaptability in complex networks.



INTERIOR GATEWAY PROTOCOL (IGP)

- IGP is used within a single 'autonomous system'.
- An autonomous system is a network or a group of networks under a common administration and with common routing policies.
- Examples of IGPs:
  - RIP (Routing Information Protocol)
  - OSPF (Open Shortest Path First)
  - EIGRP (Enhanced Interior Gateway Routing Protocol)
  - IS-IS (Intermediate System to Intermediate System)

EXTERIOR GATEWAY PROTOCOL (EGP)

- is a type of routing protocol used to exchange routing information between different autonomous systems (ASes) on the internet.
- Autonomous systems are distinct networks or groups of networks under separate administrative control, often managed by different organizations, such as internet service providers (ISPs) or large enterprises.
- Example of EGP:
  - BGP (Border Gateway Protocol)
    - *eBGP (External BGP):* Used to exchange routing information between different ASes.
    - *iBGP (Internal BGP):* Used within an AS to ensure all routers have consistent BGP routing information, even though it's primarily an IGP.

ROUTING INFORMATION PROTOCOL V1

- It has 2 version RIPv1 & RIPv2.
- Open standard protocol – supported in every networking device (like: Cisco, Juniper, etc.)
- Classful routing protocol – subnetting not supported.
- Updates are broadcasted (even to a Non-RIP configured router) via 255.255.255.255.
- Metric based on: Hop count.
- Maximum hops allowed: 15
- Maximum routers allowed: 16 (1+15)
- Supports load balancing.
- Entire routing table is exchanged after every 30seconds.

RIP TIMER

- Update timer
  - Time between consecutive updates.
  - 30 seconds
- Invalid timer
  - Time that router waits to hear updates.
  - The route is marked unreachable if there is no update during this interval.
  - 180 seconds
- Flush timer
  - Time before the invalid route is purged/removed from the routing table.
  - 240 seconds

ADVANTAGES & DISADVANTAGES

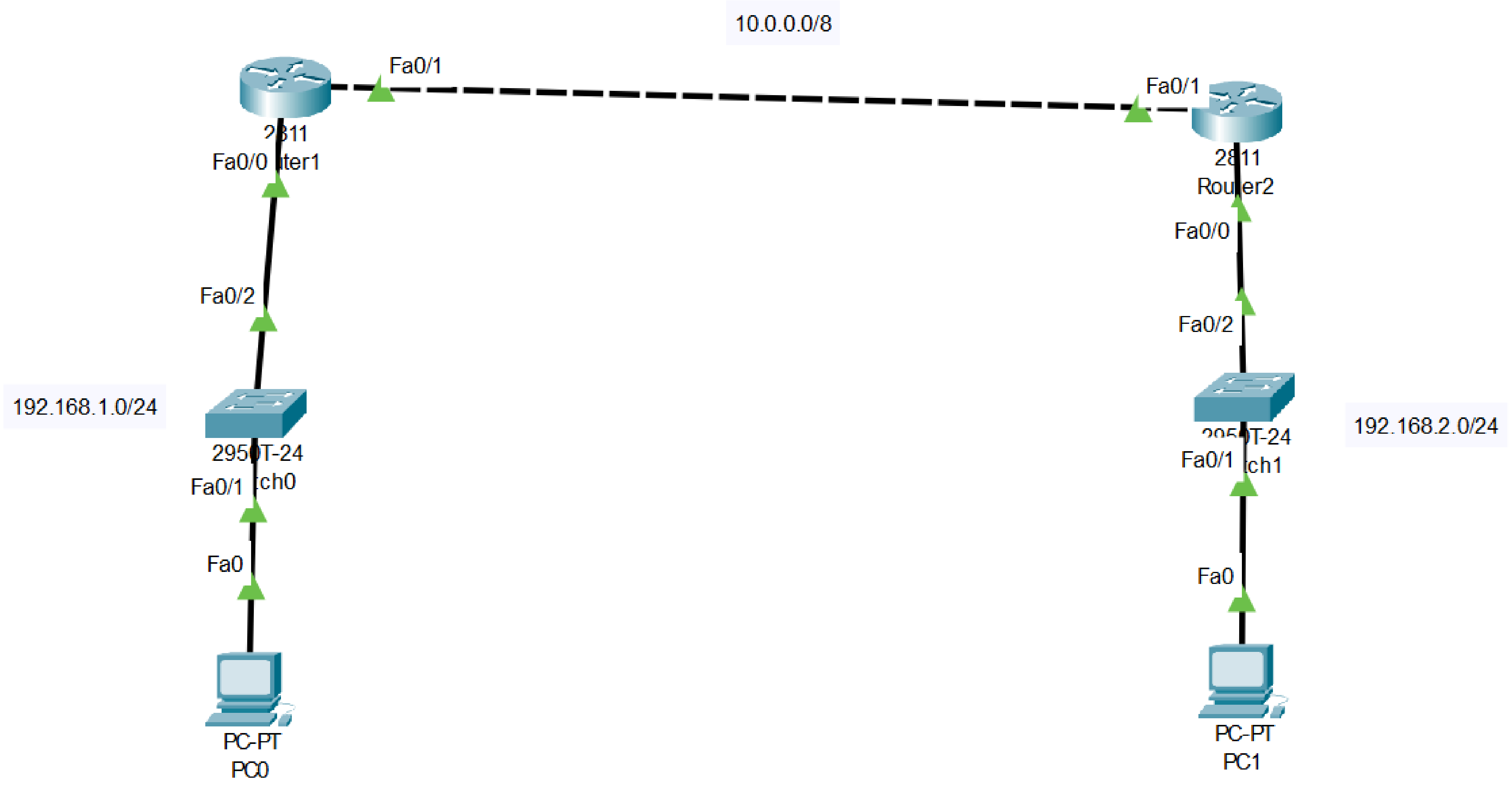
- Advantages:
  - Easy to configure
  - No design constraints
  - No complexity
  - Less overhead

- Disadvantages:
  - Bandwidth utilization is very high as broadcast for every 30 seconds
  - Works only on hop count.
  - Not scalable as hop count is only 15.

ROUTING INFORMATION PROTOCOL V2

- Similar to RIPv1.
- Supports classless routing protocol.
- Supports VLSM
- Auto summary can be done on every router.
- Supports authentication.
- Trigger updates
- Uses multicast address: 224.0.0.9

CONFIGURING RIP



ROUTER R1 CONFIG

Directly connected network(s)

```
Router(config)#router rip
Router(config-router)#network 192.168.1.0
Router(config-router)#network 10.0.0.0
Router(config-router)#exit
Router(config)#exit
Router#
%SYS-5-CONFIG_I: Configured from console by console

Router#wr
Building configuration...
[OK]
Router#
```

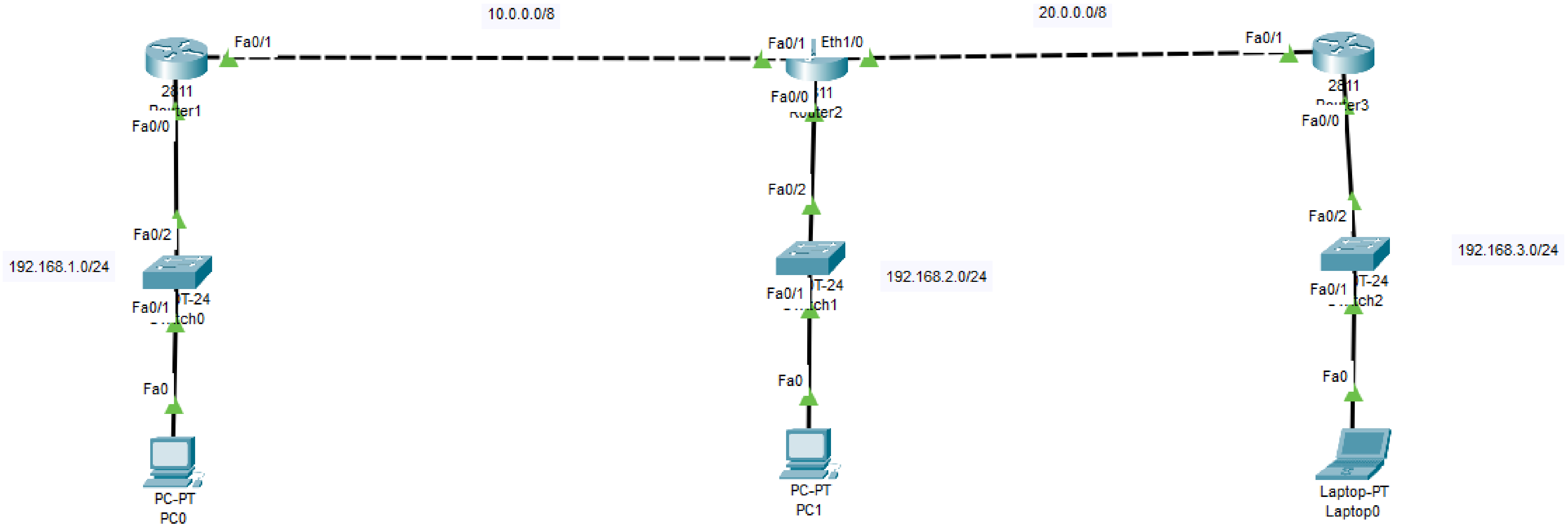
ROUTER R2 CONFIG

```
Router(config-if)#exit
Router(config)#router rip
Router(config-router)#network 192.168.2.0
Router(config-router)#network 10.0.0.0
Router(config-router)#exit
Router(config)#
Router(config)#exit
Router#
%SYS-5-CONFIG_I: Configured from console by console

Router#wr
Building configuration...
[OK]
Router#
```

TO LIST ROUTING TABLE – R1

```
Router#show 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 not set

     10.0.0.0/8 is variably subnetted, 2 subnets, 2 masks
C       10.0.0.0/8 is directly connected, FastEthernet0/1
L       10.0.0.2/32 is directly connected, FastEthernet0/1
R    192.168.1.0/24 [120/1] via 10.0.0.1, 00:00:23, FastEthernet0/1
     192.168.2.0/24 is variably subnetted, 2 subnets, 2 masks
C       192.168.2.0/24 is directly connected, FastEthernet0/0
L       192.168.2.1/32 is directly connected, FastEthernet0/0
```

3 ROUTERS RIP CONFIG



IGRP

- Interior Gateway Routing Protocol.
- Used for finding route in an autonomous system.
- It's a distance vector routing protocol (works on basis of hops).
- Its cisco proprietary product.
- It supports a maximum of 100 routers.
- Metric based on: bandwidth, delay, reliability, load, MTU size.
- Its classful routing protocol (fixed length subnet mask)
- Consumes more bandwidth than EIGRP.
- IGRP is not supported after IOS 12.3 release.

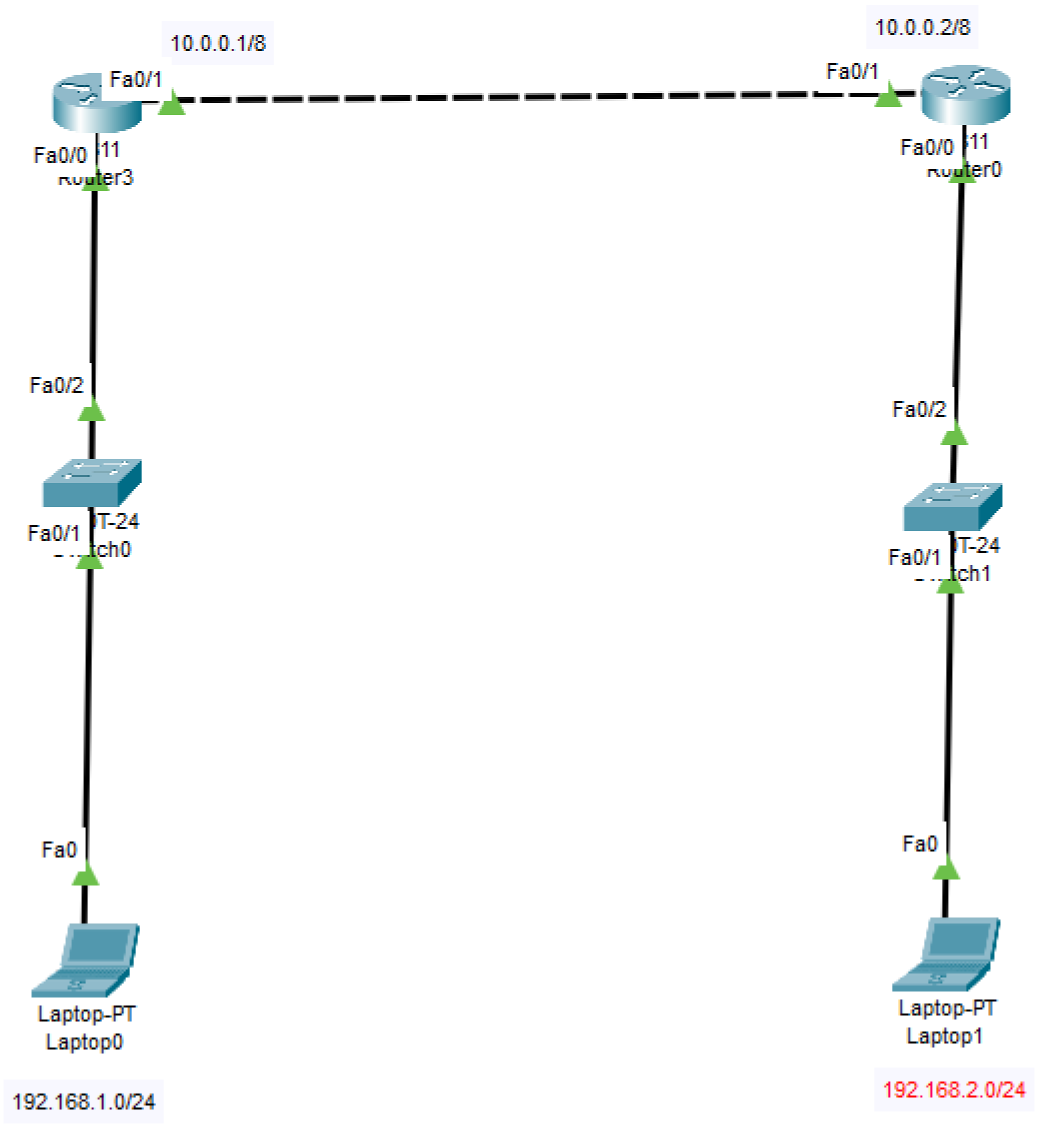
EIGRP

- Enhanced Interior Gateway Routing Protocol.
- It's a hybrid routing protocol and has both characteristics of
  - Distance Vector Routing Protocol
  - Link State
- It's Cisco proprietary product.
- Its successor of IGRP.
- Metric based on: Bandwidth, Delay, Load, Reliability.
- Convergence is faster, as it uses DUAL (Diffusing Update Algorithm)
  - *DUAL* – is used to calculate and maintain loop-free, efficient routing paths within a network. It ensures that routers have consistent and accurate routing information, minimizing convergence time and preventing routing loops.

EIGRP

- Packet delivery is handled using:
  - Reliable transport protocol (RTP)
  - Reliable multicast on 224.0.0.10
  - EIGRP uses IP protocol number 88.
- Uses variable length subnet mask (VLSM).
- Classless routing protocol.
- Loop free topology

EIGRP WITH 2 ROUTERS



EIGRP ON R1

Autonomous System Number

```
R1>
R1>en
R1>enable
R1#
R1#conf t
R1#conf terminal
Enter configuration commands, one per line.  End with CNTL/Z.
R1(config)#
R1(config)#router
R1(config)#router eig
R1(config)#router eigrp ?
  <1-65535>  Autonomous system number
R1(config)#router eigrp 1
R1(config-router)#network 192.168.1.0 255.255.255.0
R1(config-router)#network 10.0.0.0 255.0.0.0
R1(config-router)#exit
R1(config)#exit
R1#
%SYS-5-CONFIG_I: Configured from console by console

R1#wr
Building configuration...
[OK]
R1#
```

EIGRP ON R2

```
R2(config)#router eigrp 1
R2(config-router)#network 192.168.2.0 255.255.255.0
R2(config-router)#network 10.0.0.0 255.0.0.0
R2(config-router)#
%DUAL-5-NBRCHANGE: IP-EIGRP 1: Neighbor 10.0.0.1 (FastEthernet0/1) is up: new adjacency

R2(config-router)#wr
                   ^
% Invalid input detected at '^' marker.

R2(config-router)#exit
R2(config)#exit
R2#
%SYS-5-CONFIG_I: Configured from console by console

R2#wr
Building configuration...
[OK]
R2#
```

Command to check which IP routing protocol: "show ip protocols"

AUTONOMOUS SYSTEM NUMBER (ASN)

- An ASN is a globally unique identifier assigned to an Autonomous System (AS), which is a collection of IP networks and routers under a single administrative control that presents a common routing policy to the internet.
- ASNs are used to uniquely identify each AS on the global internet.
- Types of ASN:
  - Public ASN
  - Private ASN
- ASNs are 16-bit or 32-bit numbers.
  - 16-bit ASNs: Range from 1 to 65535.
  - 32-bit ASNs: Range from 65536 to 4294967295.

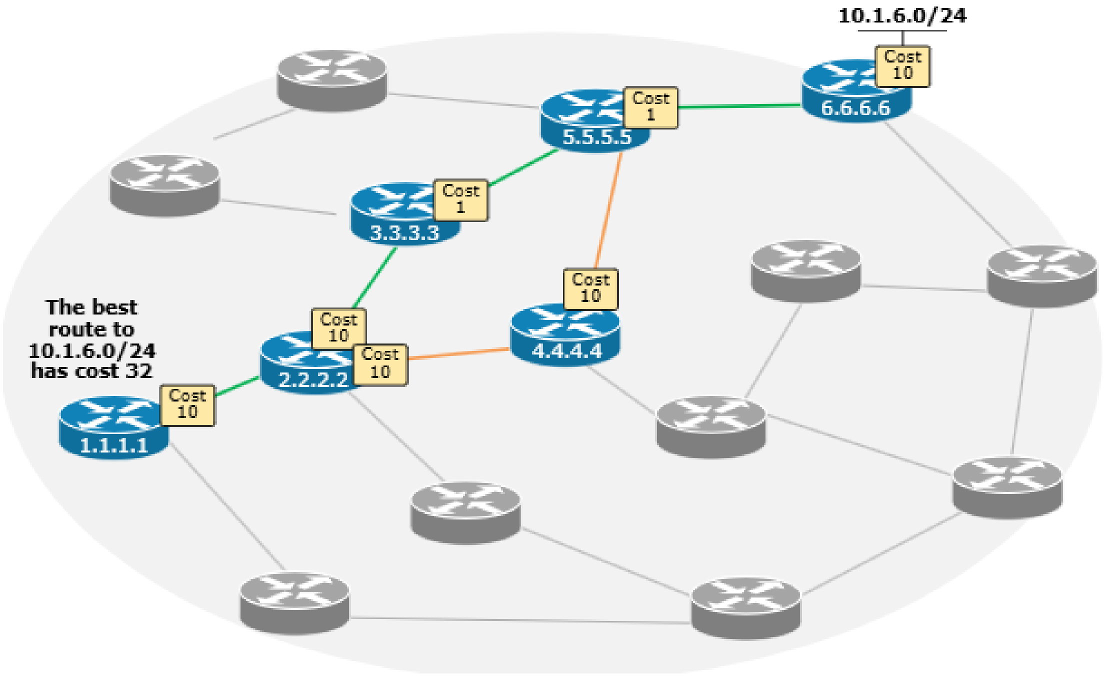
AUTONOMOUS SYSTEM NUMBER (ASN) RANGES

Range	Type	Description
1–64495	Public ASN	Assigned by Internet registries for use on the public internet.
64496–64511	Reserved	Reserved for future use.
64512–65534	Private ASN	Used for internal purposes; not visible on the public internet.
65535	Reserved	Reserved.
32-bit ASN	Extended Public	Provides more unique ASNs for the internet.

OSPF

- Open Shortest Path First.
- It is a Link-state routing protocol & a widely used protocol.
- It is an Interior Gateway protocol (IGP).
- After all the routers are connected to each other, all routers have same information about the network.
- It sends LSA (Link State Advertisements), to get the information about
  - Subnet
  - Router
    - & some other information.

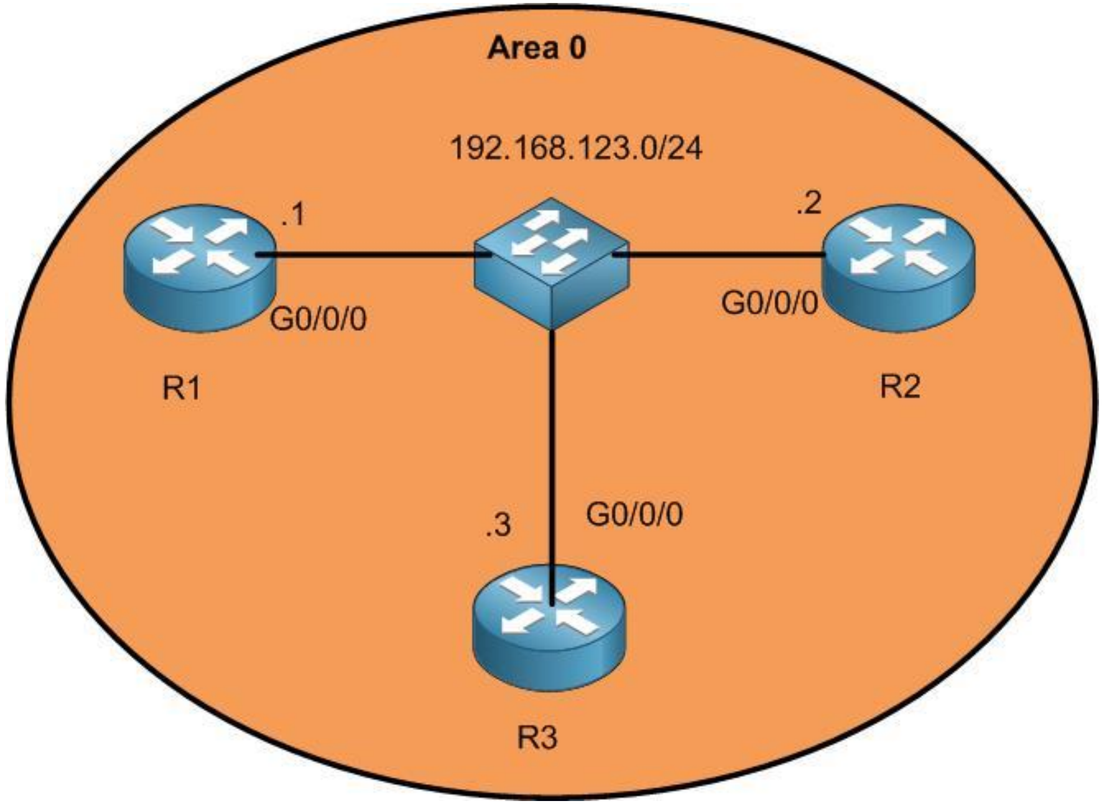
OSPF



- OSPF stores all the LSA information in a database called LSDB.
- Steps for OSPF working:
  - Becoming neighbors – two routers running OSPF on the same link agree to form a neighbor relationship.
  - Exchange database information – the neighbour routers swap their LSDB information with each other.
  - Choose the best routers – each router choose the best routes to add to its routing table based on the learned LSDB information.

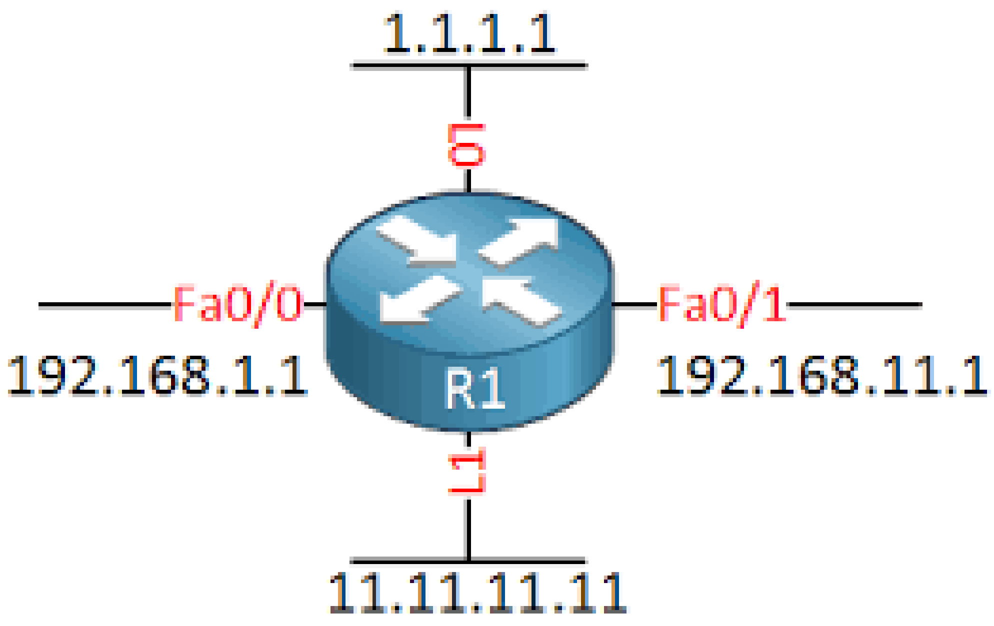
OSPF

- It uses SPF (Shortest Path First) or DIJKISTRA algo.
- Unlimited hop count.
- It supports equal cost load balancing.
- Introduced the concept of Area's to ease management and control traffic.
- All areas must be connected to area 0.
- Supports authentication.
- Uses multicast address: 224.0.0.5 & 224.0.0.6



ROUTER ID IN OSPF

- The highest IP address of the active physical interface of the router ID.
- If logical interface is configured, the highest IP address of the logical interface is Router ID.
- Loopback address gets the highest priority.



OSPF TABLES

- OSPF maintains 3 tables:
  - Neighbor table
    - This table contains information about the directly connected OSPF neighbors forming adjacency.
  - Database table
    - This table contains information about the entire view of the topology with respect to each router.
  - Routing information table
    - Routing table contains information about the best path calculated by the shortest path first algorithm in the database table.

WILDCARD

Subnet Mask	Wildcard mask
255.0.0.0	0.255.255.255
255.255.0.0	0.0.255.255
255.255.255.0	0.0.0.255

It's the opposite of subnet mask.

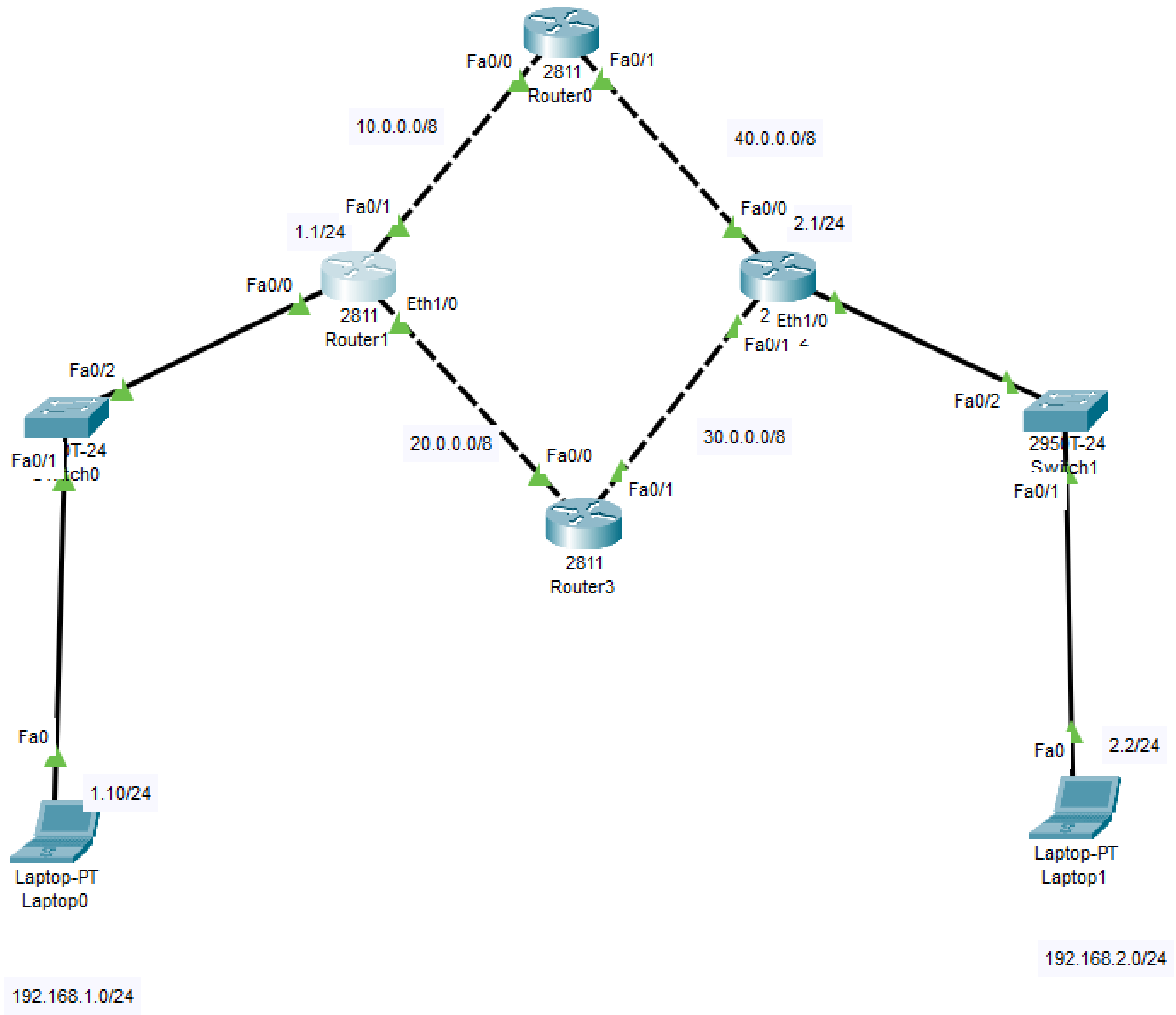
For VLSM (128)
255.255.255.255 – 255.255.255.128 = 0.0.0.127

SYNTAX OF OSPF COMMAND

```
Router(config)#route
Router(config)#router ospf 1
Router(config-router)#net
Router(config-router)#network 192.168.10.0 0.0.0.255
Router(config-router)#network 192.168.10.0 0.0.0.255 area 0
Router(config-router)#
```

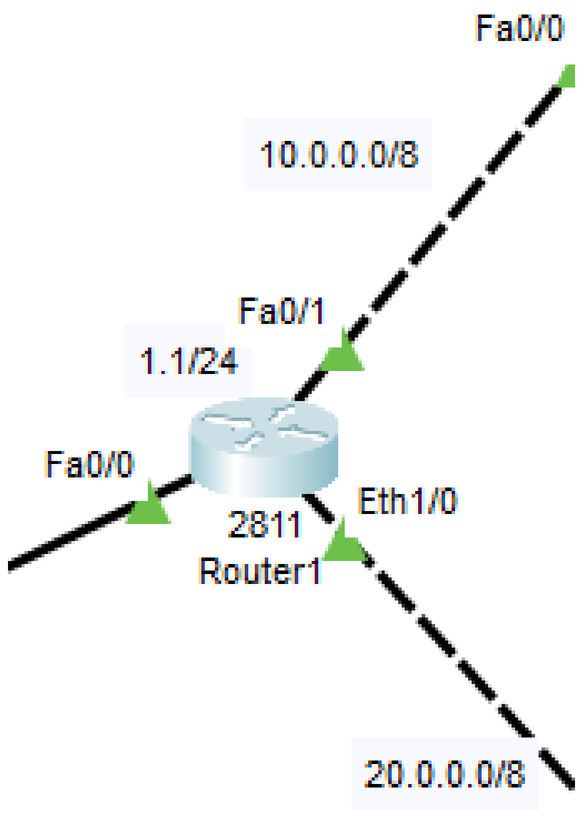
Network <ip-address-range> <wildcard-mask> area 0

OSPF



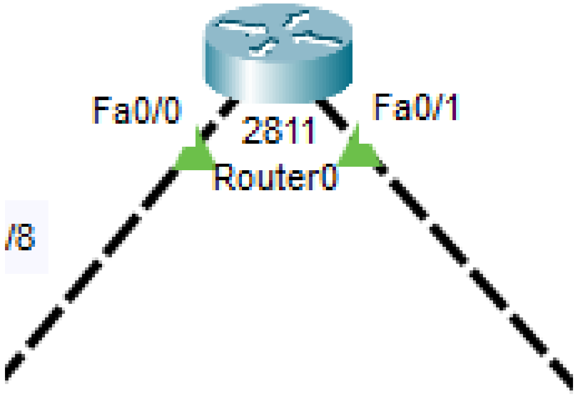
Fa0/0
2811
Router0
Fa0/1
10.0.0.0/8
40.0.0.0/8
Fa0/1
1.1/24
Fa0/0
2811
Router1
Eth1/0
Fa0/0
2.1/24
2
Eth1/0
Fa0/1
Fa0/2
20.0.0.0/8
Fa0/0
30.0.0.0/8
Fa0/1
2811
Router3
Fa0/2
Fa0/1
Fa0/1
Fa0
1.10/24
Laptop-PT
Laptop0
192.168.1.0/24
Fa0
2.2/24
Laptop-PT
Laptop1
192.168.2.0/24

OSPF CONFIGURATION ON ROUTER R1



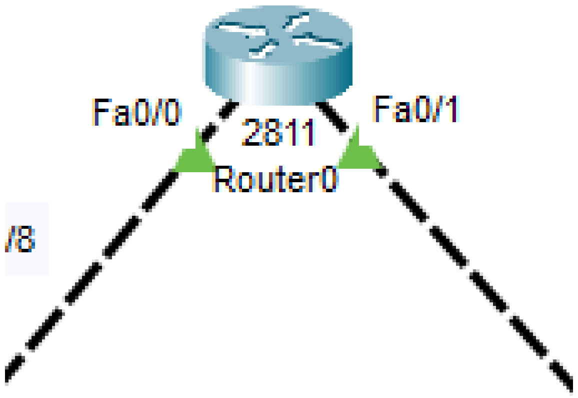

```
Router>en
Router>enable
Router#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
Router(config)#
Router(config)#rou
Router(config)#router os
Router(config)#router ospf 1
Router(config-router)#netwo
Router(config-router)#network 192.168.1.0 0.255.255.255 ar
Router(config-router)#network 192.168.1.0 0.255.255.255 area 0
Router(config-router)#network 10.0.0.0 255.0.0.0 area 0
Router(config-router)#network 20.0.0.0 255.0.0.0 are
Router(config-router)#network 20.0.0.0 255.0.0.0 area 0
Router(config-router)#exit
Router(config)#
Router(config)#
```

OSPF CONFIGURATION ON ROUTER R0



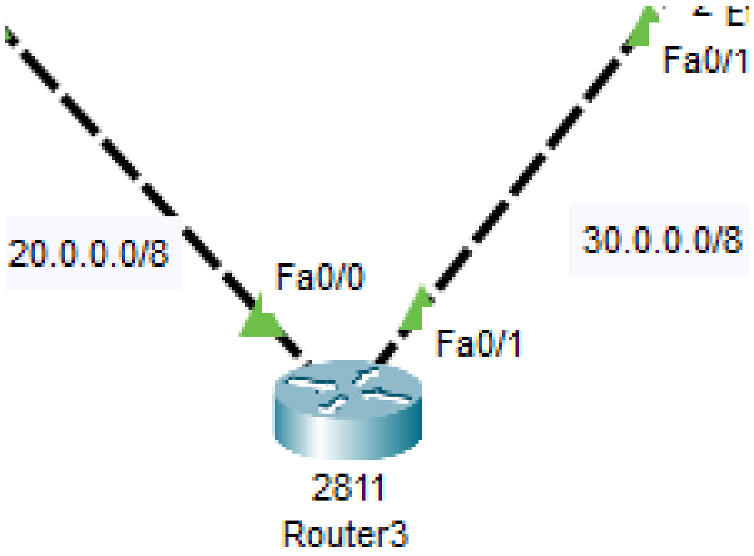

```
Router>en
Router#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
Router(config)#route
Router(config)#router os
Router(config)#router ospf 1
Router(config-router)#network 10.0.0.0 0.255.255.255 area 0
Router(config-router)#network 20
00:17:45: %OSPF-5-ADJCHG: Process 1, Nbr 192.168.1.1 on FastEthernet0/0 from LOADING to
FULL, Loading Don
% Incomplete command.
Router(config-router)#
Router(config-router)#network 40.0.0.0 0.255.255.255 area 0
Router(config-router)#exit
Router(config)#
```

OSPF CONFIGURATION ON ROUTER R0



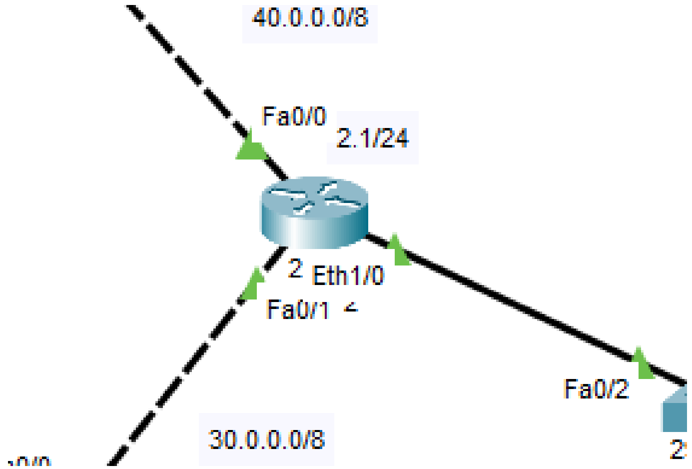

```
Router>en
Router#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
Router(config)#route
Router(config)#router os
Router(config)#router ospf 1
Router(config-router)#network 10.0.0.0 0.255.255.255 area 0
Router(config-router)#network 20
00:17:45: %OSPF-5-ADJCHG: Process 1, Nbr 192.168.1.1 on FastEthernet0/0 from LOADING to
FULL, Loading Don
% Incomplete command.
Router(config-router)#
Router(config-router)#network 40.0.0.0 0.255.255.255 area 0
Router(config-router)#exit
Router(config)#
```

OSPF CONFIGURATION ON ROUTER R3



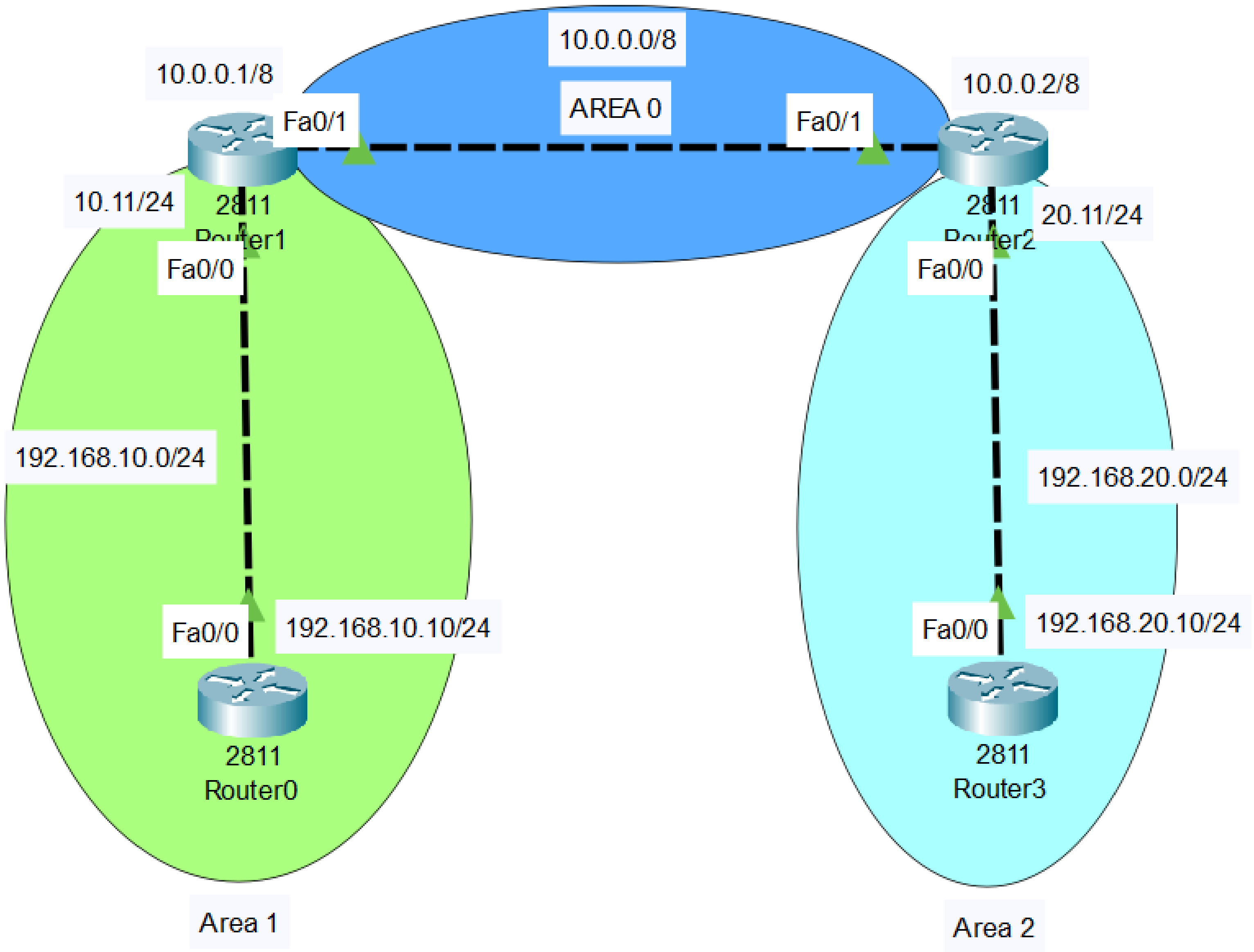

```
Router>en
Router#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
Router(config)#route
Router(config)#router os
Router(config)#router ospf 1
Router(config-router)#network 10.0.0.0 0.255.255.255 area 0
Router(config-router)#network 20
00:17:45: %OSPF-5-ADJCHG: Process 1, Nbr 192.168.1.1 on FastEthernet0/0 from LOADING to
FULL, Loading Don
% Incomplete command.
Router(config-router)#
Router(config-router)#network 40.0.0.0 0.255.255.255 area 0
Router(config-router)#exit
Router(config)#
```

OSPF CONFIGURATION ON ROUTER R2




```
Router>en
Router#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
Router(config)#
Router(config)#rout
Router(config)#router osp
Router(config)#router ospf 1
Router(config-router)#network 30.0.0.0 0.255.255.255 area 0
Router(config-router)#network 40.0.0.0 0.255.255.255 ar
00:26:12: %OSPF-5-ADJCHG: Process 1, Nbr 30.0.0.1 on FastEthernet0/1 from LOADING to
FULL, Loading Done
e
% Incomplete command.
Router(config-router)#network 40.0.0.0 0.255.255.255 are
Router(config-router)#network 40.0.0.0 0.255.255.255 area 0
Router(config-router)#network 192.168.2.0
00:26:26: %OSPF-5-ADJCHG: Process 1, Nbr 40.0.0.2 on FastEthernet0/0 from LOADING to
FULL, Loading Done

% Incomplete command.
Router(config-router)#network 192.168.2.0 0.0.255.255 are
Router(config-router)#network 192.168.2.0 0.0.255.255 area 0
Router(config-router)#exit
Router(config)#
Router(config)#
```

OSPF MULTI AREA



OSPF MULTI AREA – ROUTER 1 – AREA 0

```
Router>en
Router#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
Router(config)#router ospf
Router(config)#router ospf ?
  <1-65535>  Process ID
Router(config)#router ospf 1
Router(config-router)#network 10.0.0.0 0.255.255.255 area 0
Router(config-router)#
00:25:39: %OSPF-5-ADJCHG: Process 1, Nbr 192.168.20.11 on FastEthernet0/1 from LOADING to
FULL, Loading Done
```

Verify the neighbor on Router 1

```
Router#show ip ospf neighbor

Neighbor ID     Pri   State           Dead Time   Address         Interface
192.168.20.11     1   FULL/BDR        00:00:33    10.0.0.2        FastEthernet0/1
Router#
```

OSPF MULTI AREA – ROUTER 2 – AREA 0

```
Router>en
Router#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
Router(config)#router ospf 1
Router(config-router)#network 10.0.0.0 0.255.255.255 area 0
Router(config-router)#
Router(config-router)#
00:25:37: %OSPF-5-ADJCHG: Process 1, Nbr 192.168.10.11 on FastEthernet0/1 from LOADING to
FULL, Loading Done
```

Verify the neighbor on Router 2

```
Router#show ip ospf neighbor


Neighbor ID     Pri   State           Dead Time   Address         Interface
192.168.10.11     1   FULL/DR         00:00:36    10.0.0.1        FastEthernet0/1
Router#
```

OSPF MULTI AREA – ROUTER 1 – AREA 1

Router 1

```
Router>en
Router#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
Router(config)#router
Router(config)#router os
Router(config)#router ospf 1
Router(config-router)#netwo
Router(config-router)#network 192.168.10.0 0.0.0.255 area 1
Router(config-router)#exit
```

Router 0

```
Router>en
Router#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
Router(config)#route
Router(config)#router os
Router(config)#router ospf 1
Router(config-router)#netw
Router(config-router)#network 192.168.10.0 0.0.0.255 area 1
Router(config-router)#
00:47:55: %OSPF-5-ADJCHG: Process 1, Nbr 192.168.10.11 on FastEthernet0/0 from LOADING to
FULL, Loading Done

Router(config-router)#
```

LISTING ROUTES – ROUTER 2

```
Router#show 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 not set

     10.0.0.0/8 is variably subnetted, 2 subnets, 2 masks
C       10.0.0.0/8 is directly connected, FastEthernet0/1
L       10.0.0.2/32 is directly connected, FastEthernet0/1
O IA 192.168.10.0/24 [110/2] via 10.0.0.1, 00:08:14, FastEthernet0/1
     192.168.20.0/24 is variably subnetted, 2 subnets, 2 masks
C       192.168.20.0/24 is directly connected, FastEthernet0/0
L       192.168.20.11/32 is directly connected, FastEthernet0/0
```

LISTING OSPF EVENTS – ROUTER 1

```
Router#debug ip ospf events
OSPF events debugging is on
Router#
00:55:22: OSPF: Rcv hello from 192.168.10.10 area 1 from FastEthernet0/0 192.168.10.10

00:55:22: OSPF: End of hello processing

00:55:28: OSPF: Rcv hello from 192.168.20.11 area 0 from FastEthernet0/1 10.0.0.2

00:55:28: OSPF: End of hello processing

00:55:32: OSPF: Rcv hello from 192.168.10.10 area 1 from FastEthernet0/0 192.168.10.10

00:55:32: OSPF: End of hello processing

00:55:38: OSPF: Rcv hello from 192.168.20.11 area 0 from FastEthernet0/1 10.0.0.2

00:55:38: OSPF: End of hello processing
```

To disable debugging:

```
Router#unde
Router#undebug all
All possible debugging has been turned off
Router#
```

OSPF MULTI AREA – ROUTER 2 – AREA 2

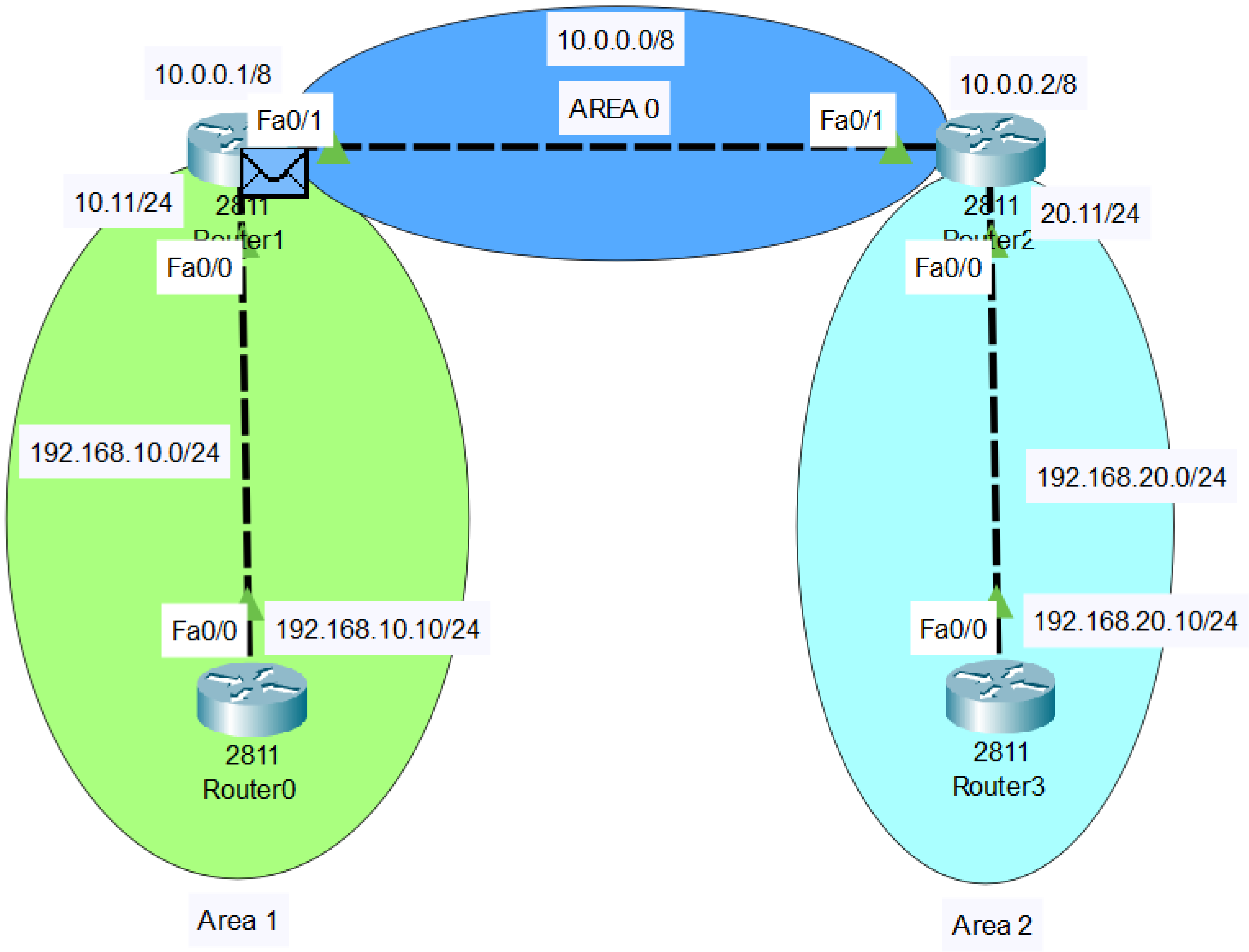
Router 2

```
Router#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
Router(config)#router os
Router(config)#router ospf 1
Router(config-router)#network 192.168.20.0 0.0.0.255 area 2
Router(config-router)#
```

Router 3

```
Router>
Router>en
Router#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
Router(config)#router
Router(config)#router os
Router(config)#router ospf 1
Router(config-router)#network 192.168.20.0 0.0.0.255 area 2
Router(config-router)#exit
Router(config)#
01:03:32: %OSPF-5-ADJCHG: Process 1, Nbr 192.168.20.11 on FastEthernet0/0 from LOADING to
FULL, Loading Done
```

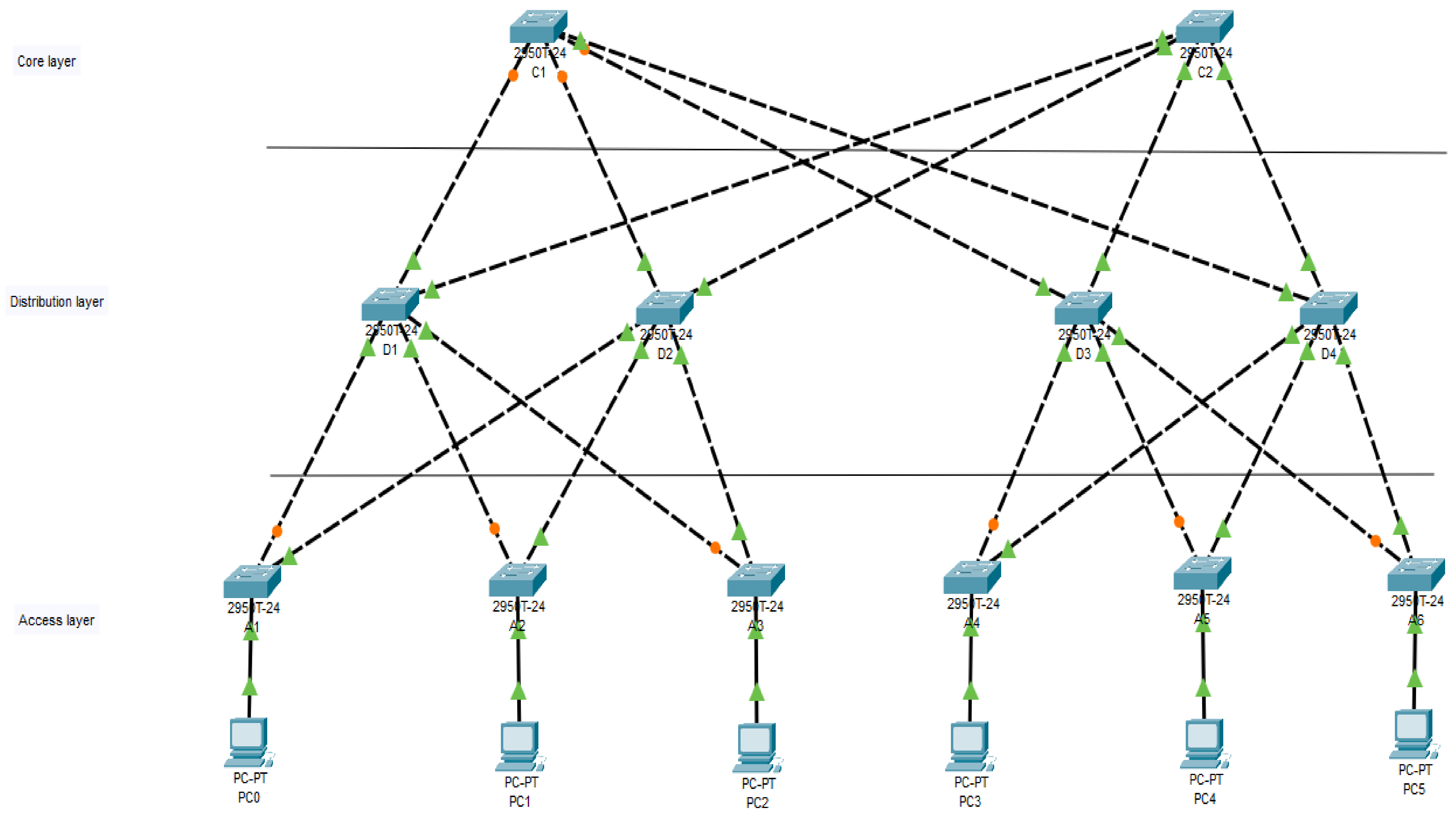
PINGING FROM ROUTER 0 TO ROUTER 3



Scenario 1

Fire	Last Status	Source	Destination	Type	Color	Time(sec)	Periodic	Num	Edit	Delete
	Successful	Router0	Router3	ICMP		0.000	N	0	(edit)	

Delete

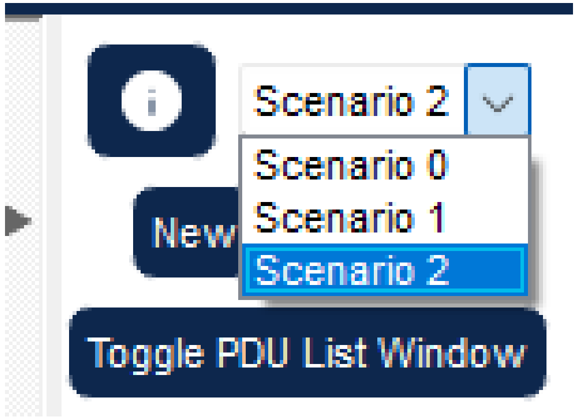


Core layer
Distribution layer
Access layer
2950T-24
C1
2950T-24
C2
2950T-24
D1
2950T-24
D2
2950T-24
D3
2950T-24
D4
2950T-24
A1
2950T-24
A2
2950T-24
A3
2950T-24
A4
2950T-24
A5
2950T-24
A6
PC-PT
PC0
PC-PT
PC1
PC-PT
PC2
PC-PT
PC3
PC-PT
PC4
PC-PT
PC5

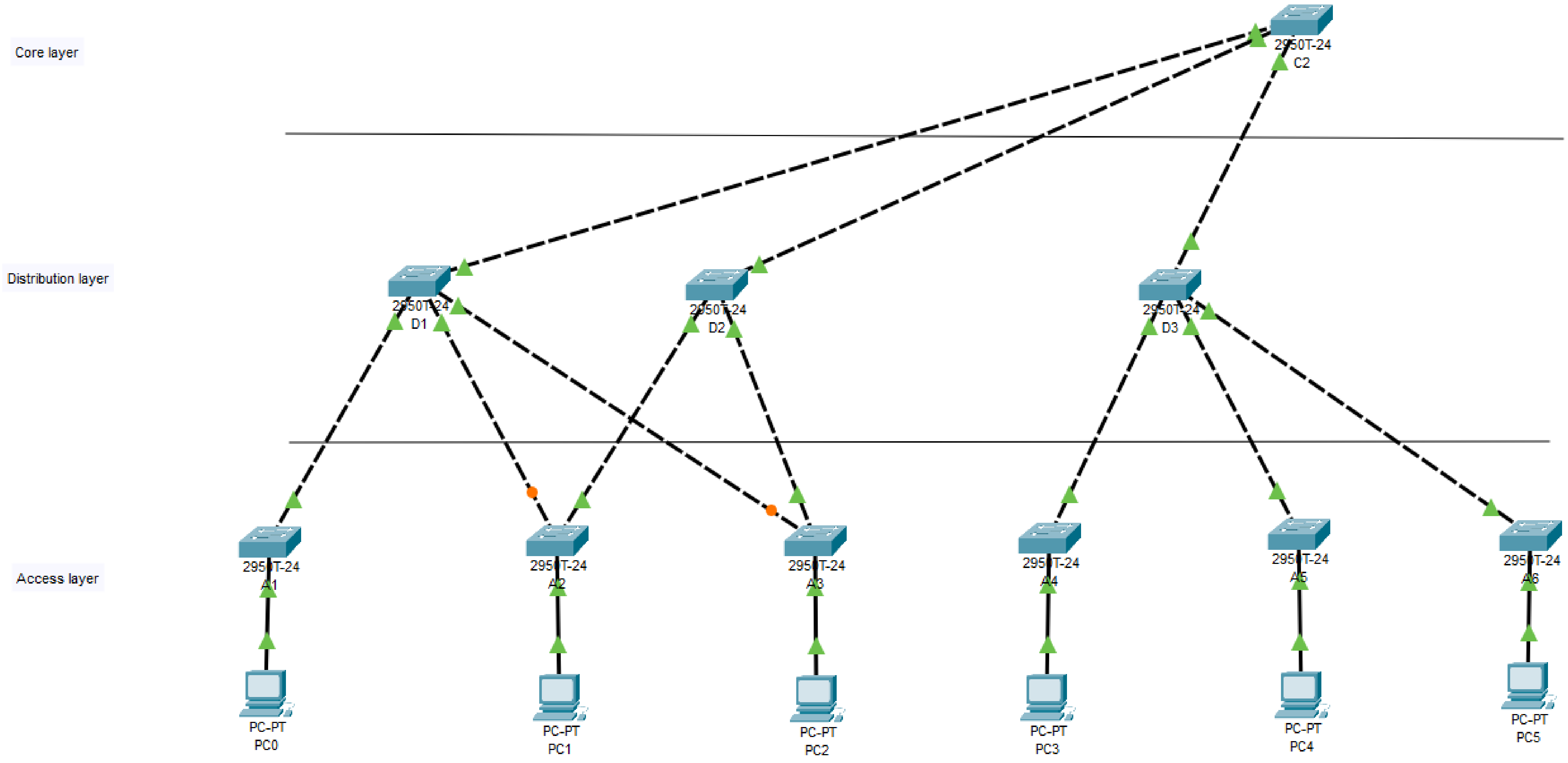
TASK

1. Capture ARP details from PC2 to PC4 for the following network.
2. Delete the uplink between A1 & D2 switches and ping from PC0 to PC5
3. Delete the uplink between C1 & D4 & ping PC0 to PC5.
4. Delete D4 uplink & ping PC0 to PC5.
5. Delete C1 uplink & ping PC0 to PC5.

Note: for every task, create a new scenario.



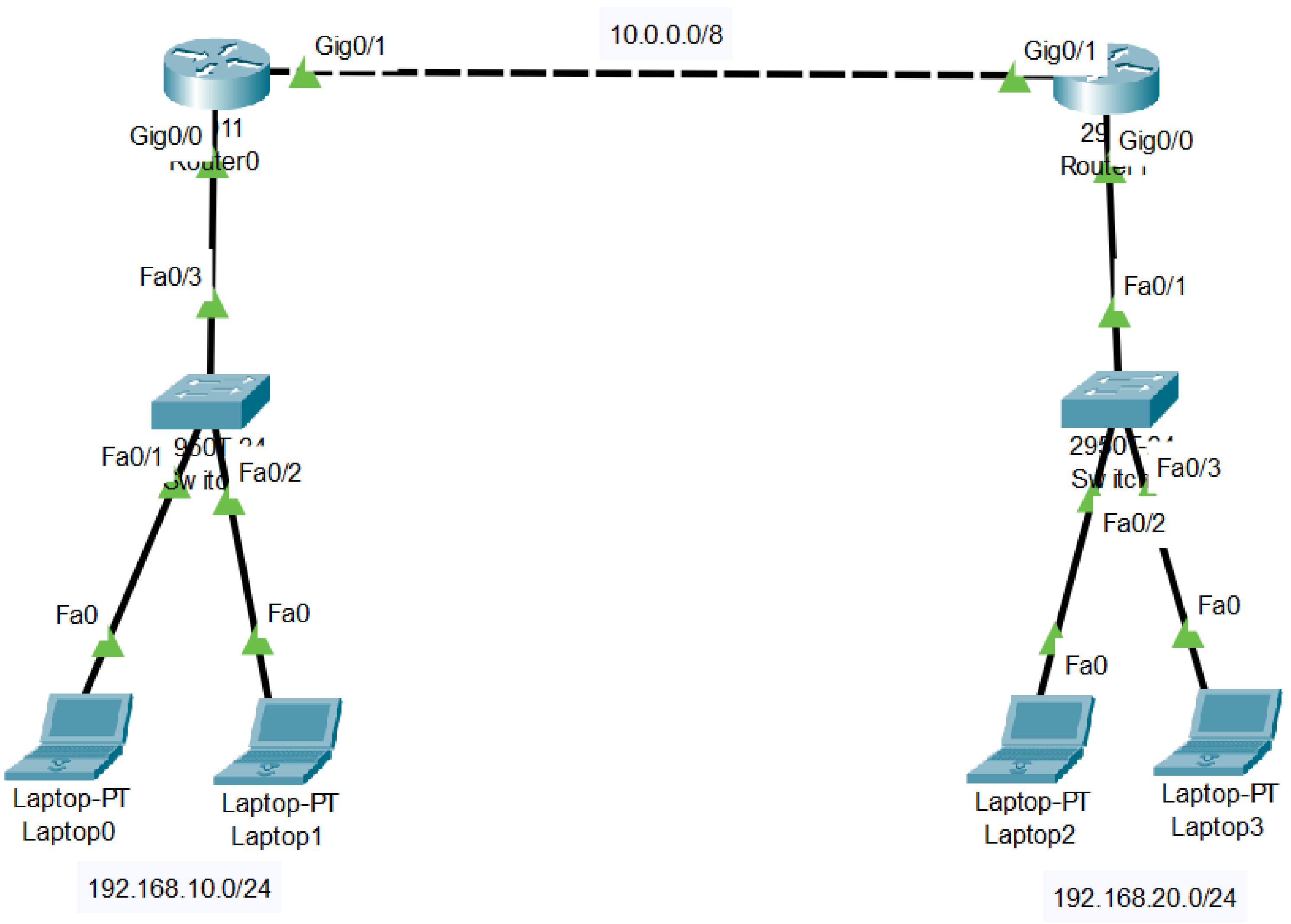
FINAL OUTPUT



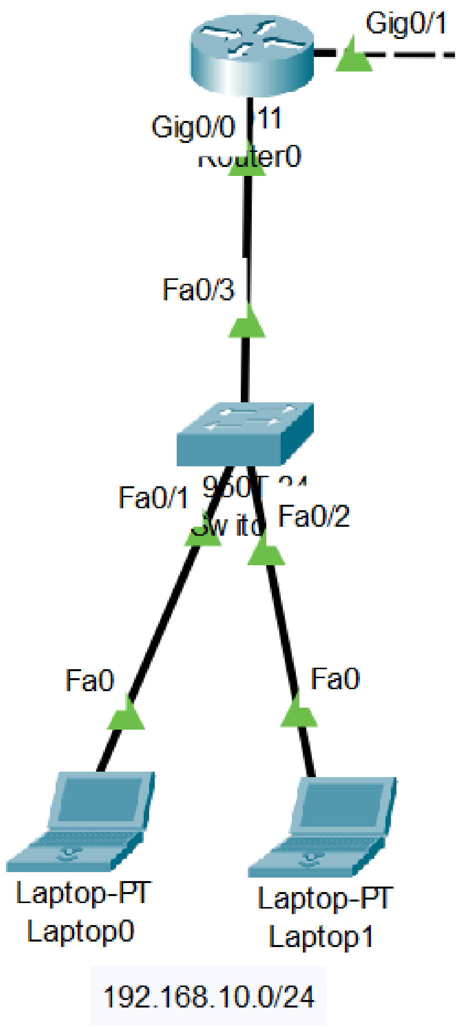
DEFAULT ROUTING

- Default routing is a method used to forward packets to a default route when no specific route to the destination network exists in the routing table.
- Default Route is represented as:
  - IPv4: 0.0.0.0/0
  - IPv6: ::/0
- Default routing is used in:
  - Acts as a "catch-all" route for traffic destined to unknown networks.
  - Ensures connectivity beyond directly connected networks.

DEFAULT ROUTING - ARCHITECTURE



DEFAULT ROUTING – ROUTER R0

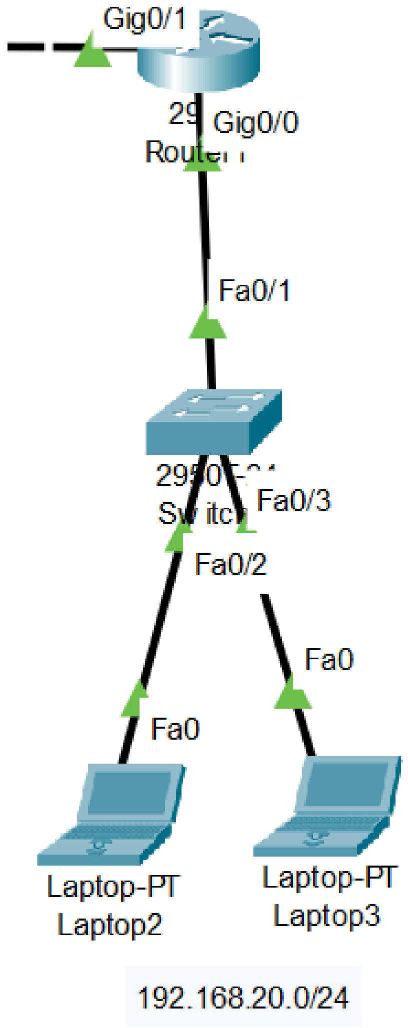


- Router R0 configuration

```
Router#show ip protocols
Router#
Router#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
Router(config)#int
Router(config)#interface g
Router(config)#interface gigabitEthernet 0/1
Router(config-if)#ip rout
Router(config-if)#ip rou
```

```
Router(config-if)#ip route 0.0.0.0 0.0.0.0 10.0.0.1
%Invalid next hop address (it's this router)
Router(config)#ip route 0.0.0.0 0.0.0.0 10.0.0.2
Router(config)#
```

DEFAULT ROUTING – ROUTER R1



- Router R1 configuration

```
Router>enable
Router#
Router#configure terminal
Enter configuration commands, one per line.  End with CNTL/Z.
Router(config)#interface GigabitEthernet0/1
Router(config-if)#ip route 0.0.0.0 0.0.0.0 10.0.0.1
Router(config)#exit
```

DEFAULT ROUTING – OUTPUT

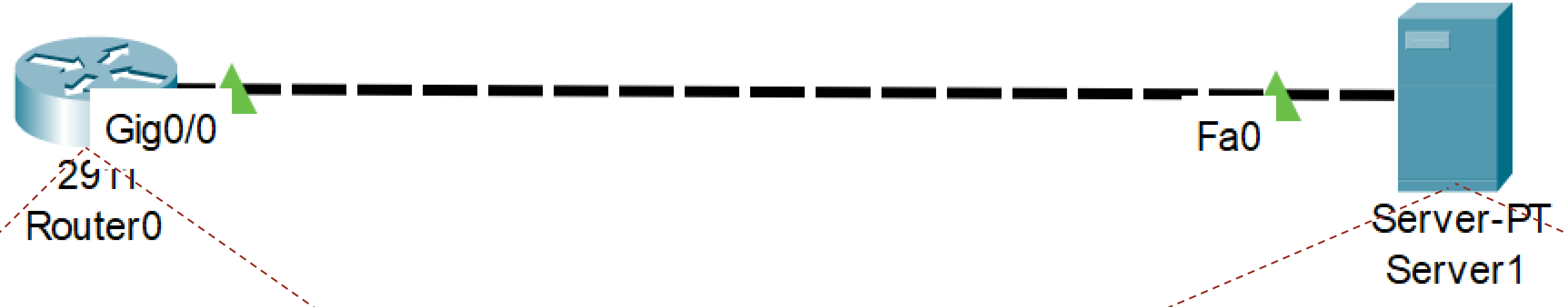
- Before Default Routing configuration:

```
C:\>ping 192.168.20.10

Pinging 192.168.20.10 with 32 bytes of data:

Reply from 192.168.10.1: Destination host unreachable.
Reply from 192.168.10.1: Destination host unreachable.
Request timed out.
Reply from 192.168.10.1: Destination host unreachable.

Ping statistics for 192.168.20.10:
    Packets: Sent = 4, Received = 0, Lost = 4 (100% loss),
```

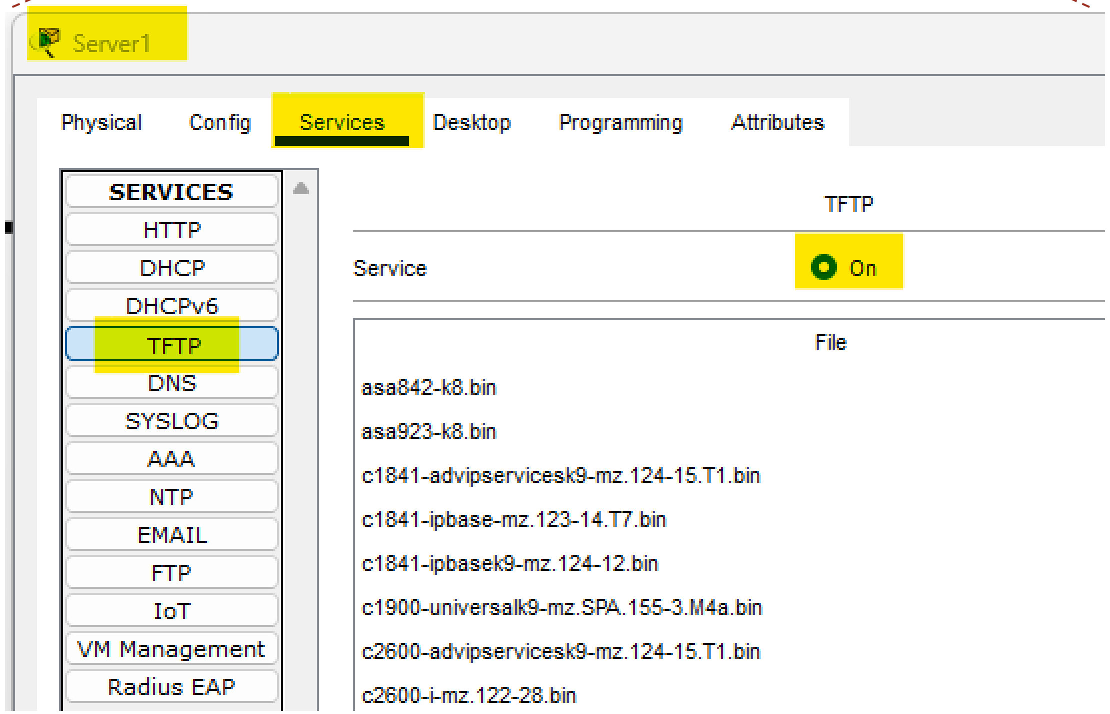
- After Default Routing configuration:

```
C:\>ping 192.168.20.10

Pinging 192.168.20.10 with 32 bytes of data:

Reply from 192.168.20.10: bytes=32 time<1ms TTL=126
Reply from 192.168.20.10: bytes=32 time<1ms TTL=126
Reply from 192.168.20.10: bytes=32 time<1ms TTL=126
Reply from 192.168.20.10: bytes=32 time<1ms TTL=126

Ping statistics for 192.168.20.10:
    Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),
Approximate round trip times in milli-seconds:
    Minimum = 0ms, Maximum = 0ms, Average = 0ms
```

BACKUP & RESTORE ROUTER




```
Router#con
Router#conf t
Enter configuration commands, one per line.
Router(config)#host
Router(config)#hostname mainRouter
mainRouter(config)#
```

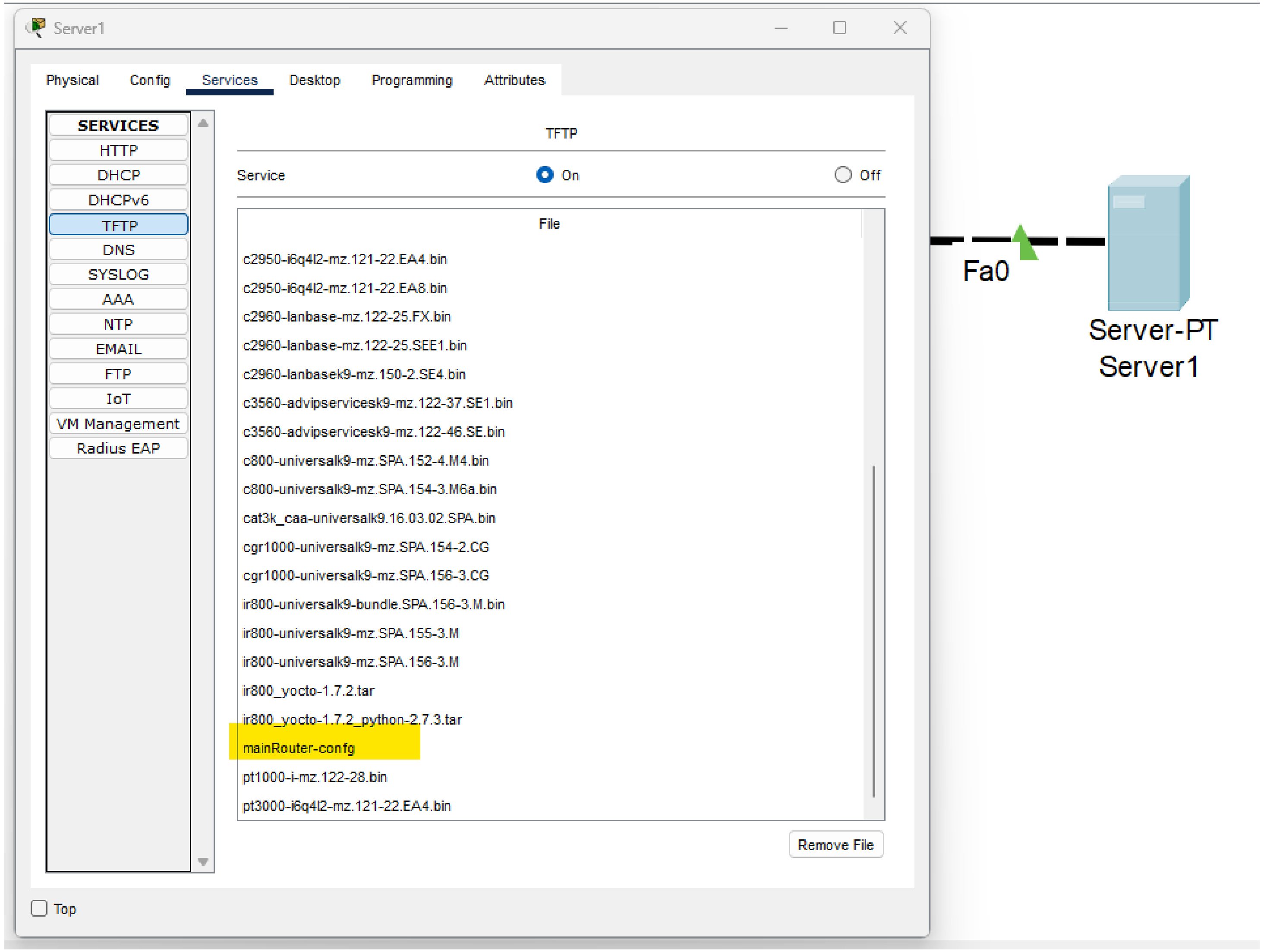


BACKUP - STEPS

- Ensure you have given IP address to both Router & Server.
- Ping both server & router.
- To create a backup on TFTP server:

```
mainRouter#copy running-config tftp:
Address or name of remote host []? 192.168.10.10
Destination filename [mainRouter-confg]?

Writing running-config....!!
[OK - 707 bytes]

707 bytes copied in 3.011 secs (234 bytes/sec)
mainRouter#
```

VERIFYING BACKUP ON TFTP SERVER



RESTORING THE CONFIG

- Firstly, making new changes:

```
mainRouter#
mainRouter#conf
mainRouter#configure ter
mainRouter#configure terminal
Enter configuration commands, one per line.  End with CNTL/Z.
mainRouter(config)#
mainRouter(config)#host
mainRouter(config)#hostname NewNameOfRouter
NewNameOfRouter(config)#
NewNameOfRouter(config)#exit
NewNameOfRouter#
%SYS-5-CONFIG_I: Configured from console by console
```

RESTORING THE CONFIG

- Running restore command on router:

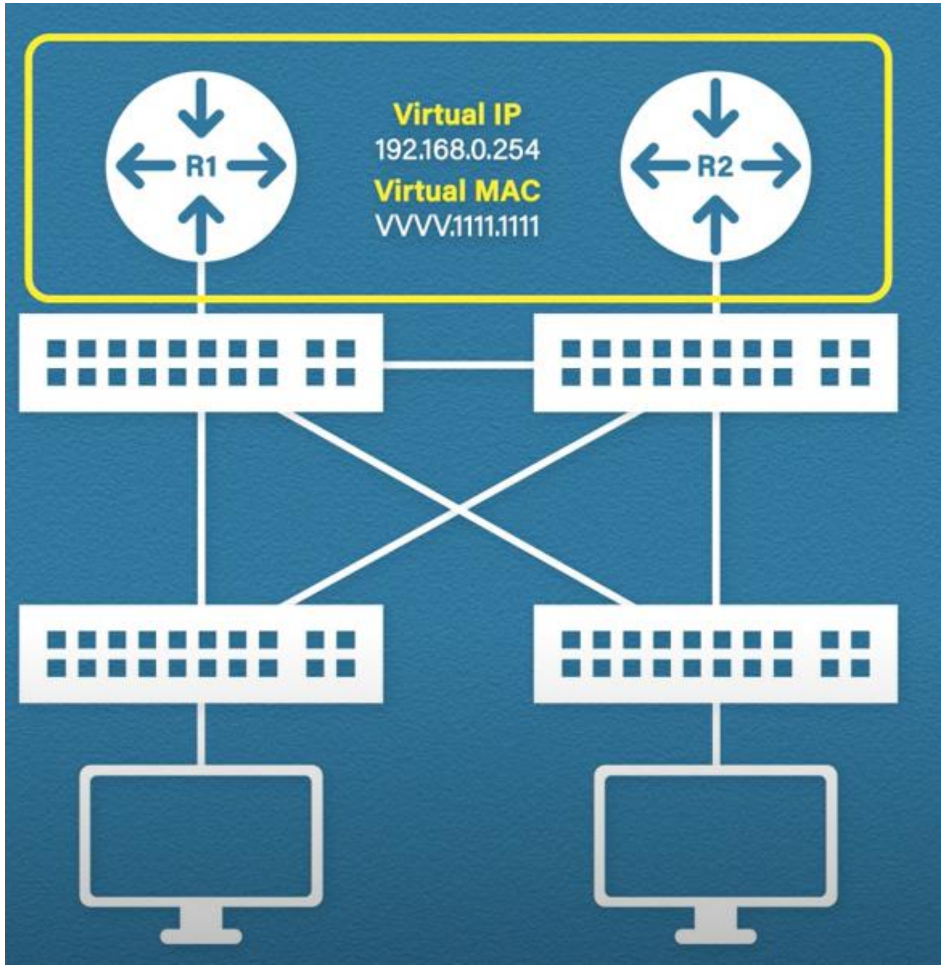
Router's name before configuration is restored

```
NewNameOfRouter#copy tftp: running-config
Address or name of remote host []? 192.168.10.10
Source filename []? mainRouter-confg
Destination filename [running-config]?

Accessing tftp://192.168.10.10/mainRouter-confg...
Loading mainRouter-confg from 192.168.10.10: !
[OK - 707 bytes]

707 bytes copied in 0.004 secs (176750 bytes/sec)
mainRouter#
%SYS-5-CONFIG_I: Configured from console by console

mainRouter#
```

Router name after configuration is restored

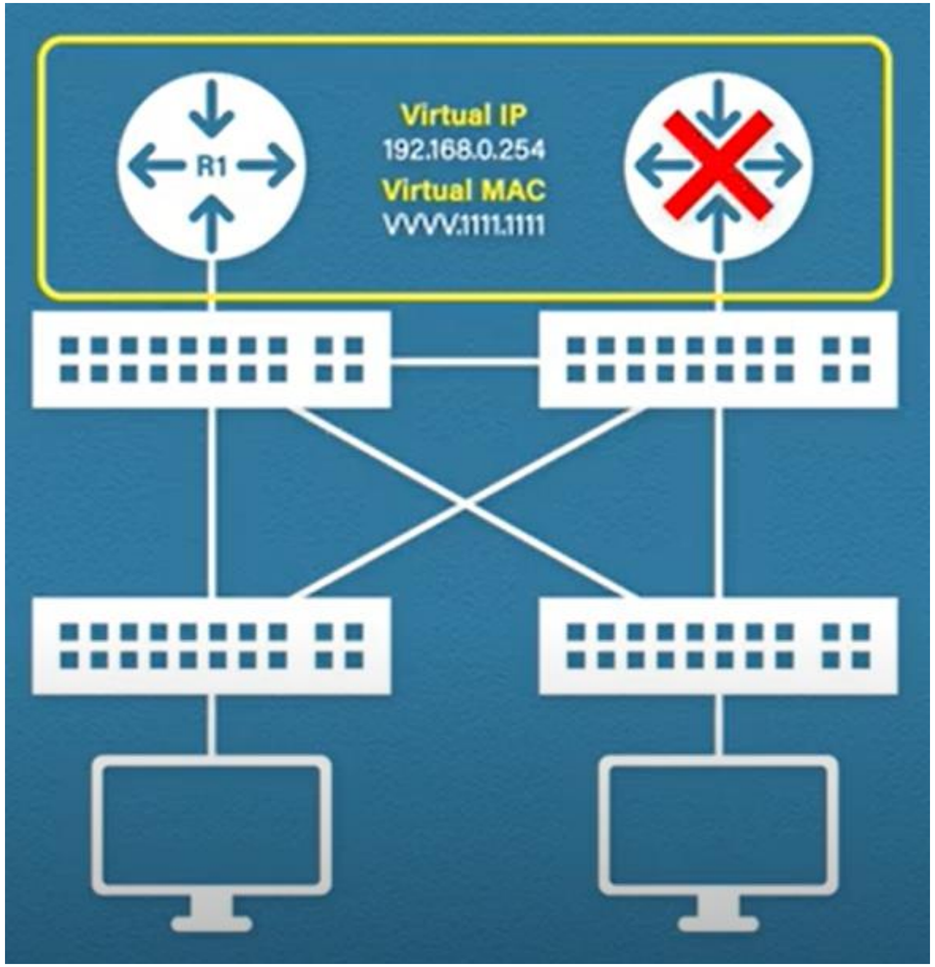
FIRST HOP REDUNDANCY PROTOCOL

- Ensures network availability by providing redundancy for the default gateway (first hop) in case of a failure.
- FHRP allows multiple routers to share a virtual IP address that acts as the default gateway for hosts on a subnet.
- If the primary gateway fails, the backup router automatically takes over, minimizing downtime.



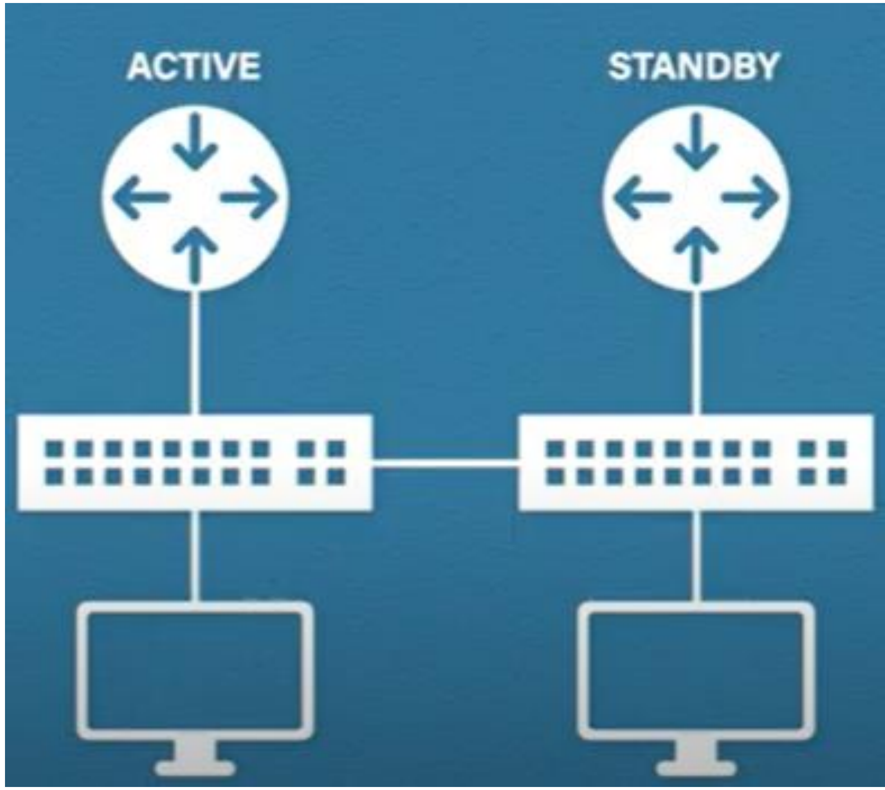
FIRST HOP REDUNDANCY PROTOCOL

- Common FHRPs:
  - HSRP
    - Hot Standby Router Protocol
    - Cisco proprietary, uses an active and standby router model.
  - VRRP
    - Virtual Router Redundancy Protocol
    - Open standard, similar to HSRP but with differences in election process and IP address usage.
  - GLBP
    - Gateway Load Balancing Protocol
    - Cisco proprietary, supports load balancing by allowing multiple active routers.



HOT STANDBY ROUTER PROTOCOL

- HSRP multicast sends & receives multicast UDP hello packets every 3 seconds.
  - In Version 1, it uses 224.0.0.2 &
  - In Version 2, it uses 224.0.0.102
- Virtual IP add is set for the group's default gateway.
- Active router election
  1. Highest priority
  2. Highest IP address

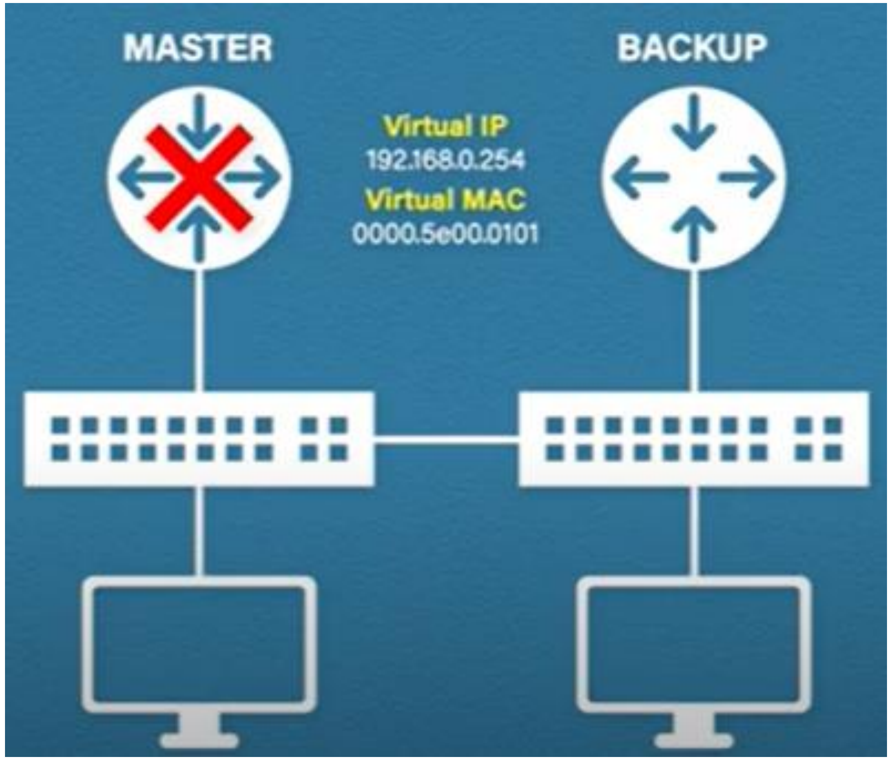


HOT STANDBY ROUTER PROTOCOL

- Router sends “Hello” packet after every 3 seconds.
- If any router fails, it “holds” for 10 seconds.
- If no response till the hold time, then standby/passive announces itself as the “active” router and send the information to network to update the MAC address table.
- If master (old) comes online, it will not replace the new master by default.

VIRTUAL ROUTER REDUNDANCY PROTOCOL

- Here we have concept of Master router & Backup router.
- Here, any 1 router will be assigned with a 'virtual IP', this makes this router as "IP address owner".
- Master router election happens on the priority of:
  1. IP Address Owner
  2. Highest Priority
  3. Highest IP Address



VIRTUAL ROUTER REDUNDANCY PROTOCOL

- Unlike HSRP, the messages within the network is only sent by "master router".
- Master router sends the multicast packets to address: 224.0.0.18
- The advertisements are sent every 1 second by default.
- It (master) has a downtime of 3 seconds.
  - & then "backup" router will assume the role of "master" router & announces itself to the network.
- If the master (old) router comes online again, it will "takeover" as master router once again.

GATEWAY LOAD BALANCING PROTOCOL

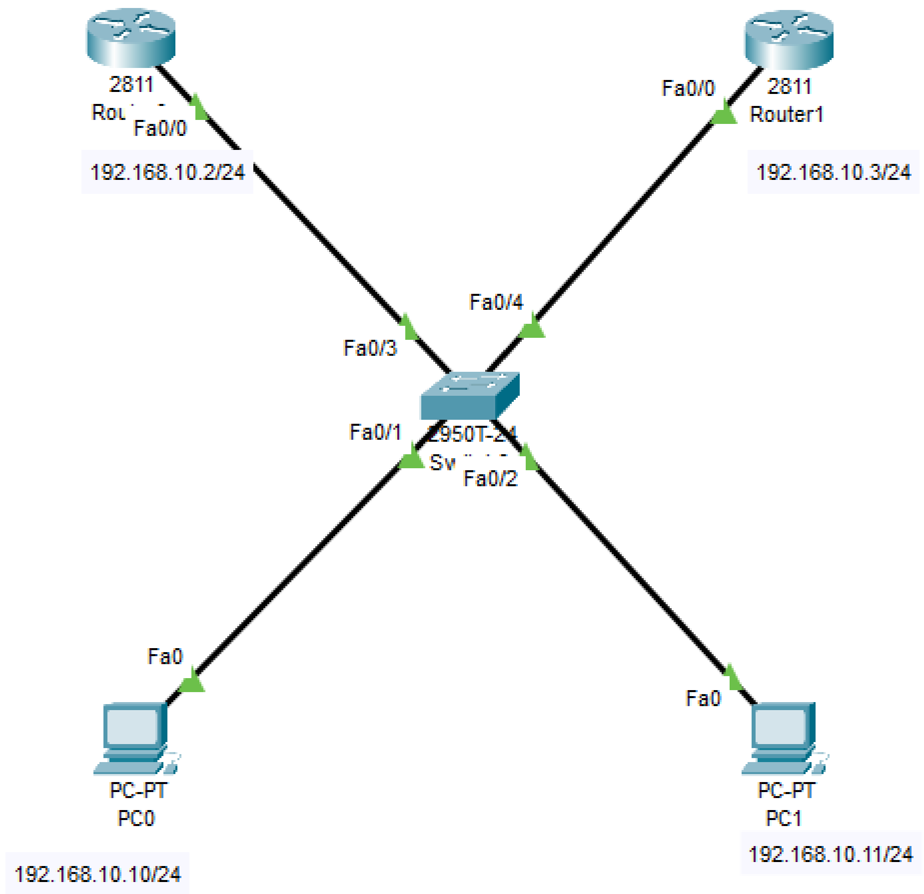
- GLBP is similar to HSRP, as it's a Cisco proprietary.
- Like HSRP, each router will send "hello" message to the network after every 3 seconds.
- It uses multicast address: 224.0.0.102
- & UDP port: 3222
- Active router election is similar to HSRP
- In GLBP, it assigns 'virtual MAC' address to each router.

FHRP TABLE FOR EXAM

	Standard	Router roles	Multicast address	MAC address	No. of virtual MAC address
HSRP	Cisco proprietary	Active/Standby	224.0.0.2 224.1.1.102	000.0C07.ACXX	ONE
VRRP	RFC 5798 (open standard)	Master/Backup	224.0.0.18	0000.5e00.01XX	ONE
GLBP	Cisco proprietary	Active/Standby	224.0.0.102	0007.b400.XXYY	Four (shared)

HOT STANDBY ROUTER PROTOCOL

- PC0 = 192.168.10.10/24
- DGW(PC0) = 192.168.10.1
- PC1 = 192.168.10.11/24
- DGW (PC1) = 192.168.10.1
- Router0 = 192.168.10.2/24
- Router1 = 192.168.10.3/24



HSRP CONFIGURATION – ROUTER 1

```
Router(config)#int fastEthernet 0/0
Router(config-if)#
Router(config-if)#standby ?
  <0-4095>   group number
  ip         Enable HSRP and set the virtual IP address
  ipv6       Enable HSRP IPv6
```

```
Router(config-if)#standby 1 ?
  ip         Enable HSRP and set the virtual IP address
  ipv6       Enable HSRP IPv6
  preempt    Overthrow lower priority Active routers
  priority   Priority level
  timers     Hello and hold timers
  track      Priority Tracking
Router(config-if)#standby 1 ip 192.168.10.1
```

```
Router(config-if)#do sh standby br
                     P indicates configured to preempt.
                     |
Interface   Grp  Pri P State    Active          Standby         Virtual IP
Fa0/0       1    100   Active   local           unknown         192.168.10.1
Router(config-if)#
```

HSRP CONFIGURATION – ROUTER 1

```
Router(config-if)#do sh standby
FastEthernet0/0 - Group 1
  State is Active
    4 state changes, last state change 00:10:54
  Virtual IP address is 192.168.10.1
  Active virtual MAC address is 0000.0C07.AC01
    Local virtual MAC address is 0000.0C07.AC01 (v1 default)
  Hello time 3 sec, hold time 10 sec
    Next hello sent in 0.132 secs
  Preemption disabled
  Active router is local
  Standby router is unknown
  Priority 100 (default 100)
  Group name is hsrp-Fa0/0-1 (default)
Router(config-if)#
```

HSRP CONFIGURATION – ROUTER 0

```
Active(config-if)#standby 1 ip 192.168.10.1
% Warning: address is not within a subnet on this interface
Active(config-if)#
Active(config-if)#do sh standby br
%HSRP-6-STATECHANGE: FastEthernet0/0 Grp 1 state Speak -> Standby

                     P indicates configured to preempt.
                     |
Interface   Grp  Pri P State    Active          Standby         Virtual IP
Fa0/0       1    100   Standby  192.168.10.3    local           192.168.10.1
Active(config-if)#
Active(config-if)#standby 1 ip 192.168.10.1
% Warning: address is not within a subnet on this interface
Active(config-if)#
%HSRP-6-STATECHANGE: FastEthernet0/0 Grp 1 state Speak -> Standby

Active(config-if)#
Active(config-if)#
```

HSRP CONFIGURATION – CHANGING PRIORITY

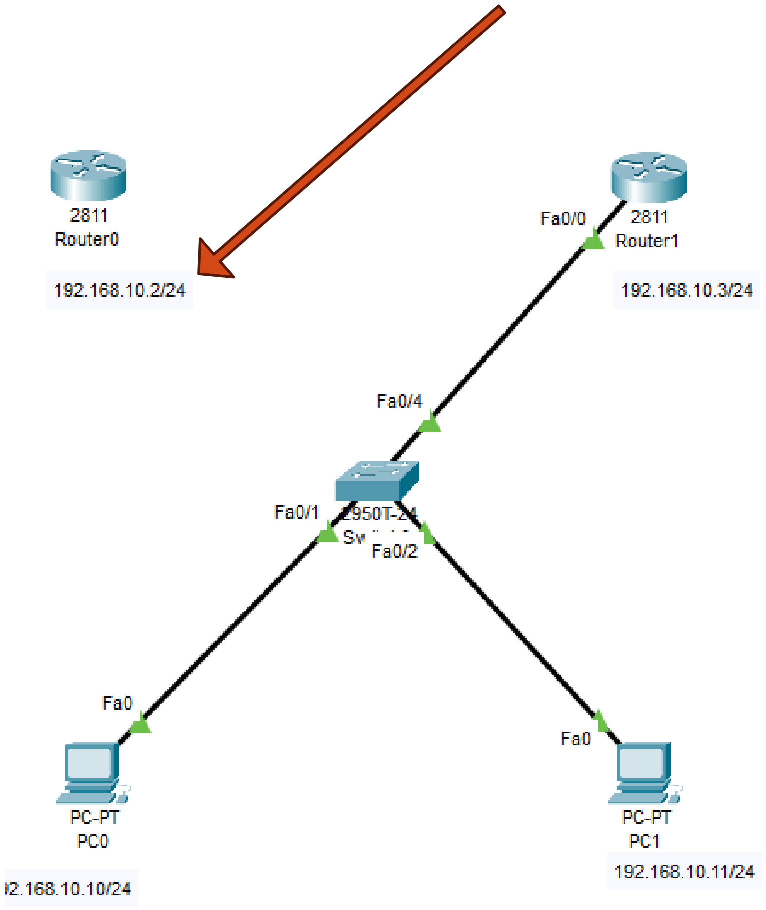
By changing priority, stand by router becomes active.

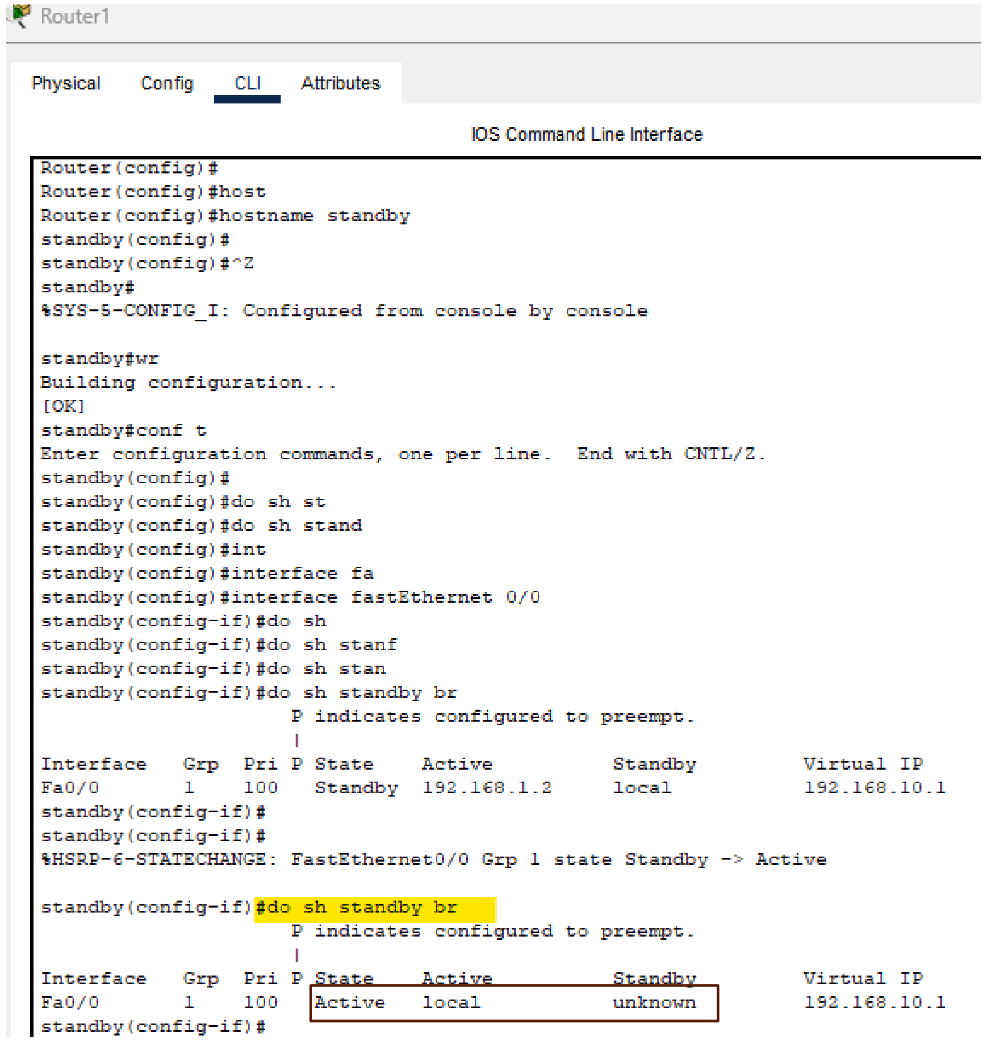
```
Active(config-if)#standby 1 pri
Active(config-if)#standby 1 priority 105
Active(config-if)#do sh standby br
                     P indicates configured to preempt.
                     |
Interface   Grp  Pri P State    Active          Standby         Virtual IP
Fa0/0       1    105   Standby  192.168.10.3    local           192.168.10.1
Active(config-if)#
Active(config-if)#standby 1 pree
Active(config-if)#standby 1 preempt
Active(config-if)#
%HSRP-6-STATECHANGE: FastEthernet0/0 Grp 1 state Standby -> Active

Active(config-if)#do sh standby br
                     P indicates configured to preempt.
                     |
Interface   Grp  Pri P State    Active          Standby         Virtual IP
Fa0/0       1    105 P Active   local           192.168.1.2     192.168.10.1
```

forcefully changing the router mode.

HSRP CONFIGURATION – DELETE ROUTER 0

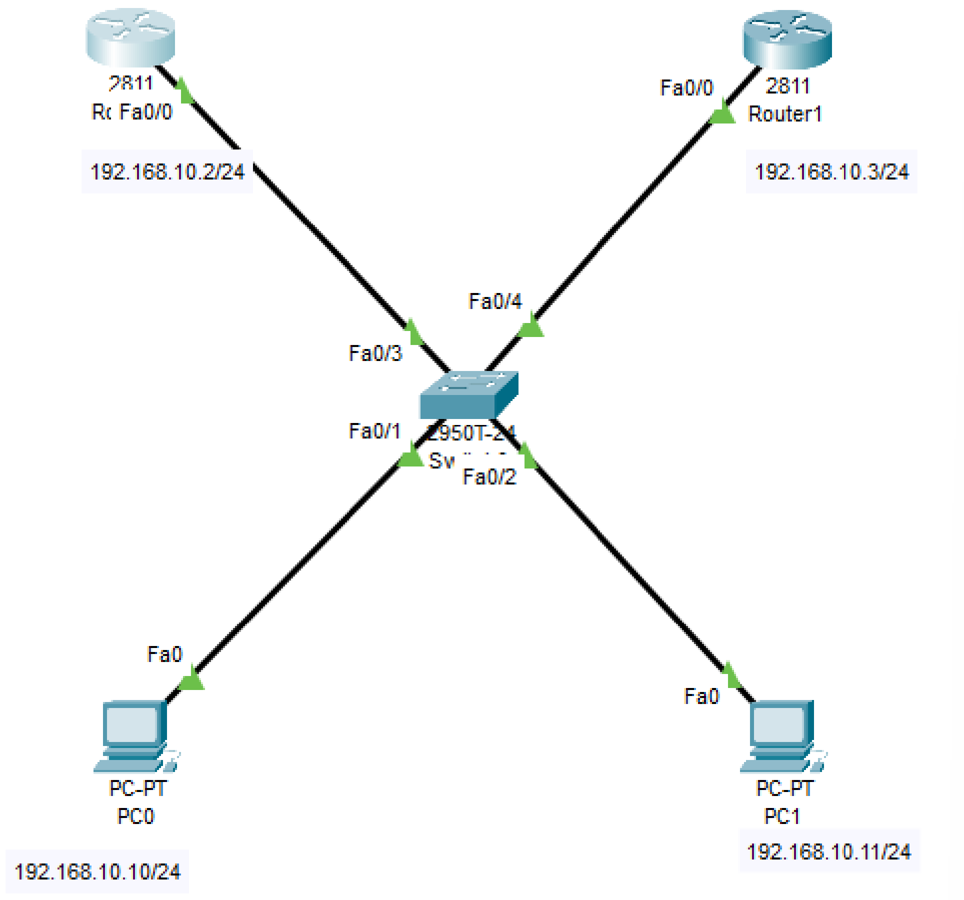
Just delete the link for the active & wait for 3 seconds. & verify on Router1

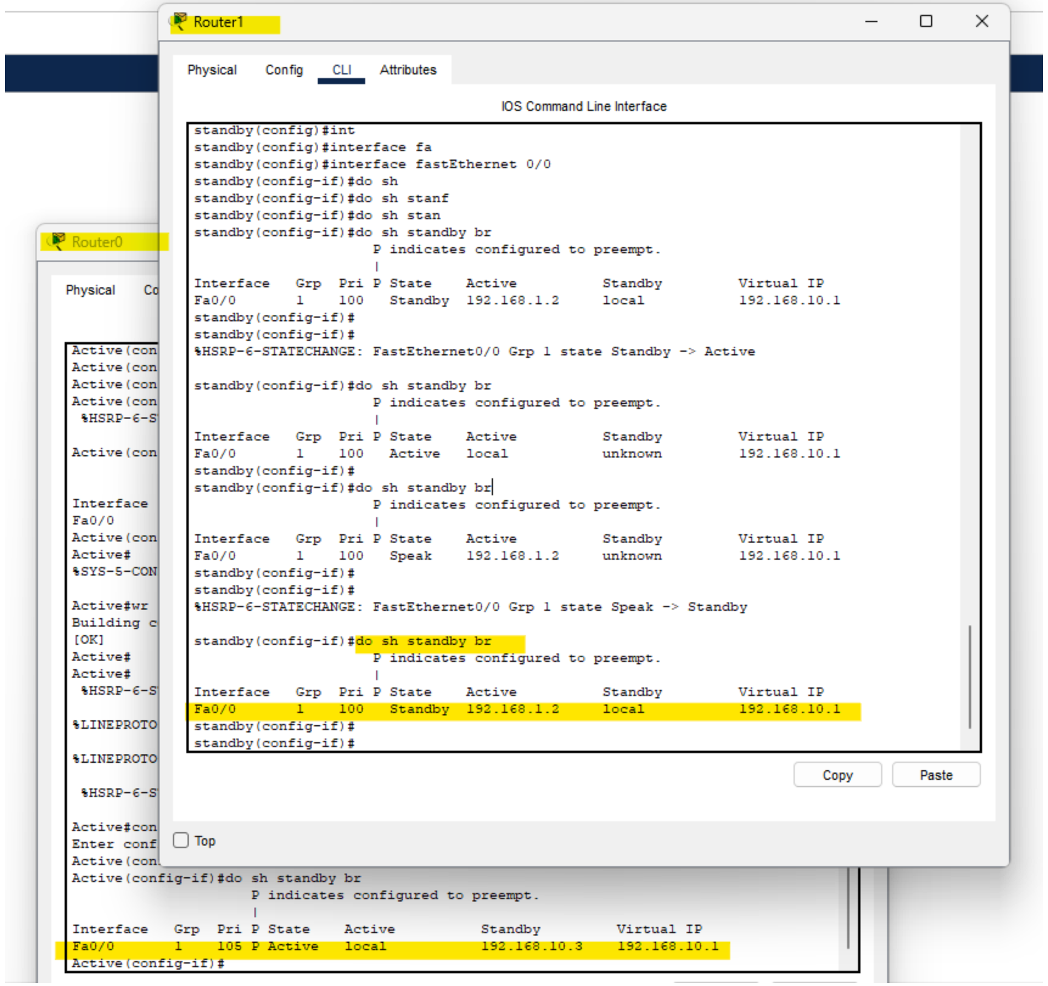





```
Router(config)#
Router(config)#host
Router(config)#hostname standby
standby(config)#
standby(config)#^Z
standby#
%SYS-5-CONFIG_I: Configured from console by console

standby#wr
Building configuration...
[OK]
standby#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
standby(config)#
standby(config)#do sh st
standby(config)#do sh stand
standby(config)#int
standby(config)#interface fa
standby(config)#interface fastEthernet 0/0
standby(config-if)#do sh
standby(config-if)#do sh stanf
standby(config-if)#do sh stan
standby(config-if)#do sh standby br
                     P indicates configured to preempt.
                     |
Interface   Grp  Pri P State    Active          Standby         Virtual IP
Fa0/0       1    100   Standby  192.168.1.2     local           192.168.10.1
standby(config-if)#
standby(config-if)#
%HSRP-6-STATECHANGE: FastEthernet0/0 Grp 1 state Standby -> Active

standby(config-if)#do sh standby br
                     P indicates configured to preempt.
                     |
Interface   Grp  Pri P State    Active          Standby         Virtual IP
Fa0/0       1    100   Active   local           unknown         192.168.10.1
standby(config-if)#
```

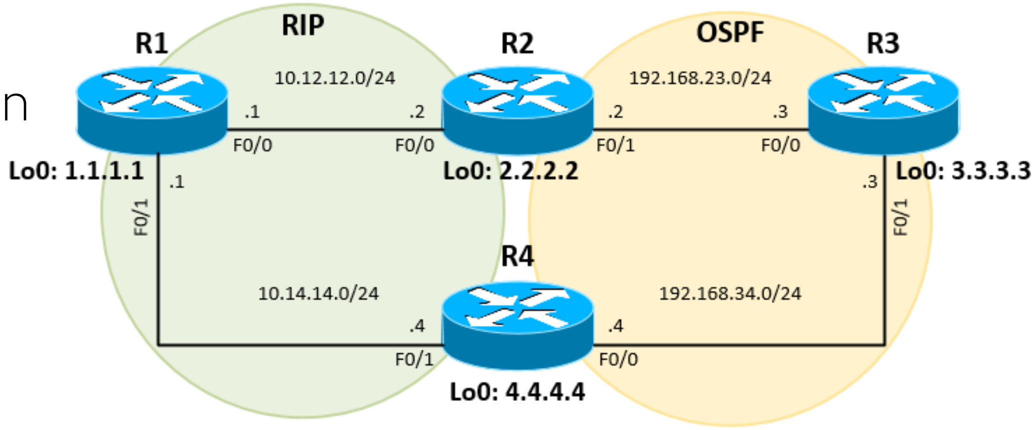
HSRP CONFIGURATION – REACTIVATION OF R0





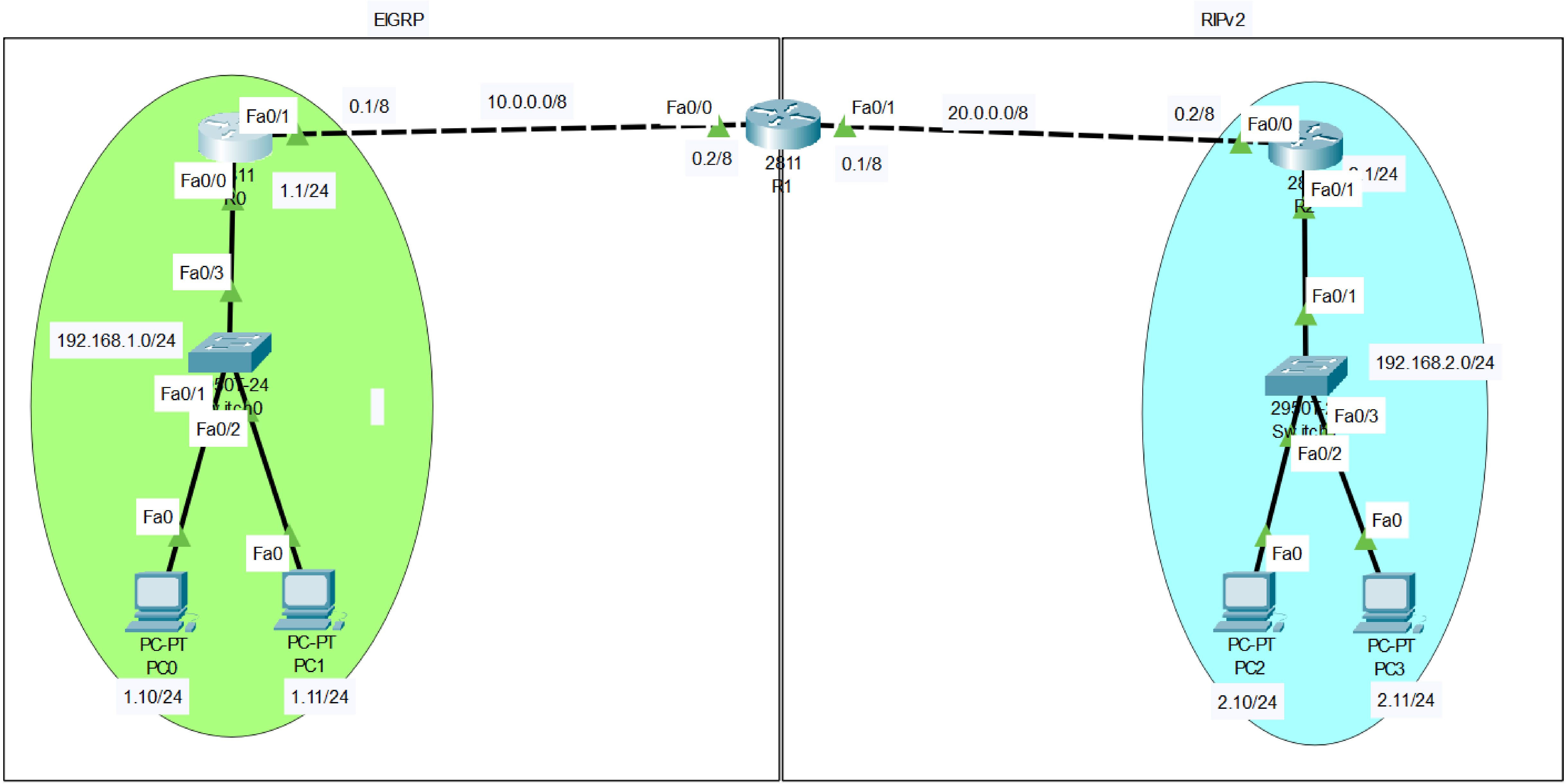
REDISTRIBUTION

- Redistribution involves sharing routes between different routing protocols, allowing for interoperation in complex network environments.



- Redistribution can occur between various routing protocols like OSPF, EIGRP, BGP, RIP, and others.
- Redistribution can be one-way (routes from one protocol are redistributed into another) or two-way (routes are shared between both protocols).
- When redistributing routes, metric values must be converted appropriately to match the receiving protocol's metric type (e.g., cost, hop count).
- Redistribution can lead to routing loops if not configured carefully, especially with two-way redistribution.

REDISTRIBUTION ON EIGRP & RIP



CONFIGURING EIGRP ON R0

```
R0#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R0(config)#
R0(config)#rout
R0(config)#router eigrp 13
R0(config-router)#network 192.168.1.0
R0(config-router)#network 10.0.0.0
R0(config-router)#no auto-su
R0(config-router)#no auto-summary
R0(config-router)#exit
```

```
R0#show ip protocols

Routing Protocol is "eigrp  13 "
  Outgoing update filter list for all interfaces is not set
  Incoming update filter list for all interfaces is not set
  Default networks flagged in outgoing updates
  Default networks accepted from incoming updates
  Redistributing: eigrp 13
```

CONFIGURING EIGRP ON R1

```
R1#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R1(config)#
R1(config)#router ei
R1(config)#router eigrp 13
R1(config-router)#network 10.0.0.0
R1(config-router)#
%DUAL-5-NBRCHANGE: IP-EIGRP 13: Neighbor 10.0.0.1 (FastEthernet0/0) is up: new adjacency

R1(config-router)#exit
R1(config)#exit
R1#
%SYS-5-CONFIG_I: Configured from console by console

R1#show ip eigrp nei
R1#show ip eigrp neighbors
IP-EIGRP neighbors for process 13
H   Address          Interface      Hold Uptime    SRTT   RTO   Q    Seq
                                    (sec)          (ms)         Cnt  Num
0   10.0.0.1         Fa0/0          13   00:00:26  40     1000  0    1

R1#
```

CONFIGURING RIP ON R1

```
R1#conf t
R1#conf terminal
Enter configuration commands, one per line.  End with CNTL/Z.
R1(config)#
R1(config)#router rip
R1(config-router)#version 2
R1(config-router)#no auto-sum
R1(config-router)#no auto-summary
R1(config-router)#network 20.0.0.0
R1(config-router)#end
R1#
%SYS-5-CONFIG_I: Configured from console by console

R1#
```

CONFIGURING RIP ON R2

```
R2>en
R2#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R2(config)#
R2(config)#router rip
R2(config-router)#version 2
R2(config-router)#no auto-summary
R2(config-router)#network 20.0.0.0
R2(config-router)#network 192.168.2.0
R2(config-router)#end
R2#
%SYS-5-CONFIG_I: Configured from console by console

R2#
```

CONFIGURING REDISTRIBUTION ON R1

```
R1#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R1(config)#
R1(config)#router eigrp 13
R1(config-router)#res
R1(config-router)#red
R1(config-router)#redistribute rip ?
  metric  Metric for redistributed routes
  <cr>
R1(config-router)#redistribute rip met
R1(config-router)#redistribute rip metric ?
  <1-4294967295>  Bandwidth metric in Kbits per second
R1(config-router)#redistribute rip metric 1 ?
  <0-4294967295>  EIGRP delay metric, in 10 microsecond units
R1(config-router)#redistribute rip metric 1 1 ?
  <0-255>  EIGRP reliability metric where 255 is 100% reliable
R1(config-router)#redistribute rip metric 1 1 255 ?
  <1-255>  EIGRP Effective bandwidth metric (Loading) where 255 is 100% loaded
R1(config-router)#redistribute rip metric 1 1 255 255 ?
  <1-65535>  EIGRP MTU of the path
R1(config-router)#redistribute rip metric 1 1 255 255 1
R1(config-router)#exit
R1(config)#
```

Metric value: **"Bandwidth" + "Delay" + "Load" + "MTU" + "Reliability"**

VALIDATING ROUTES ON R0

```
R0#show 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 not set

     10.0.0.0/8 is variably subnetted, 2 subnets, 2 masks
C       10.0.0.0/8 is directly connected, FastEthernet0/1
L       10.0.0.1/32 is directly connected, FastEthernet0/1
D EX 20.0.0.0/8 [170/2560002816] via 10.0.0.2, 00:03:00, FastEthernet0/1
     192.168.1.0/24 is variably subnetted, 2 subnets, 2 masks
C       192.168.1.0/24 is directly connected, FastEthernet0/0
L       192.168.1.1/32 is directly connected, FastEthernet0/0
D EX 192.168.2.0/24 [170/2560002816] via 10.0.0.2, 00:03:00, FastEthernet0/1
```

CONFIGURING EIGRP UNDER RIP ON R1

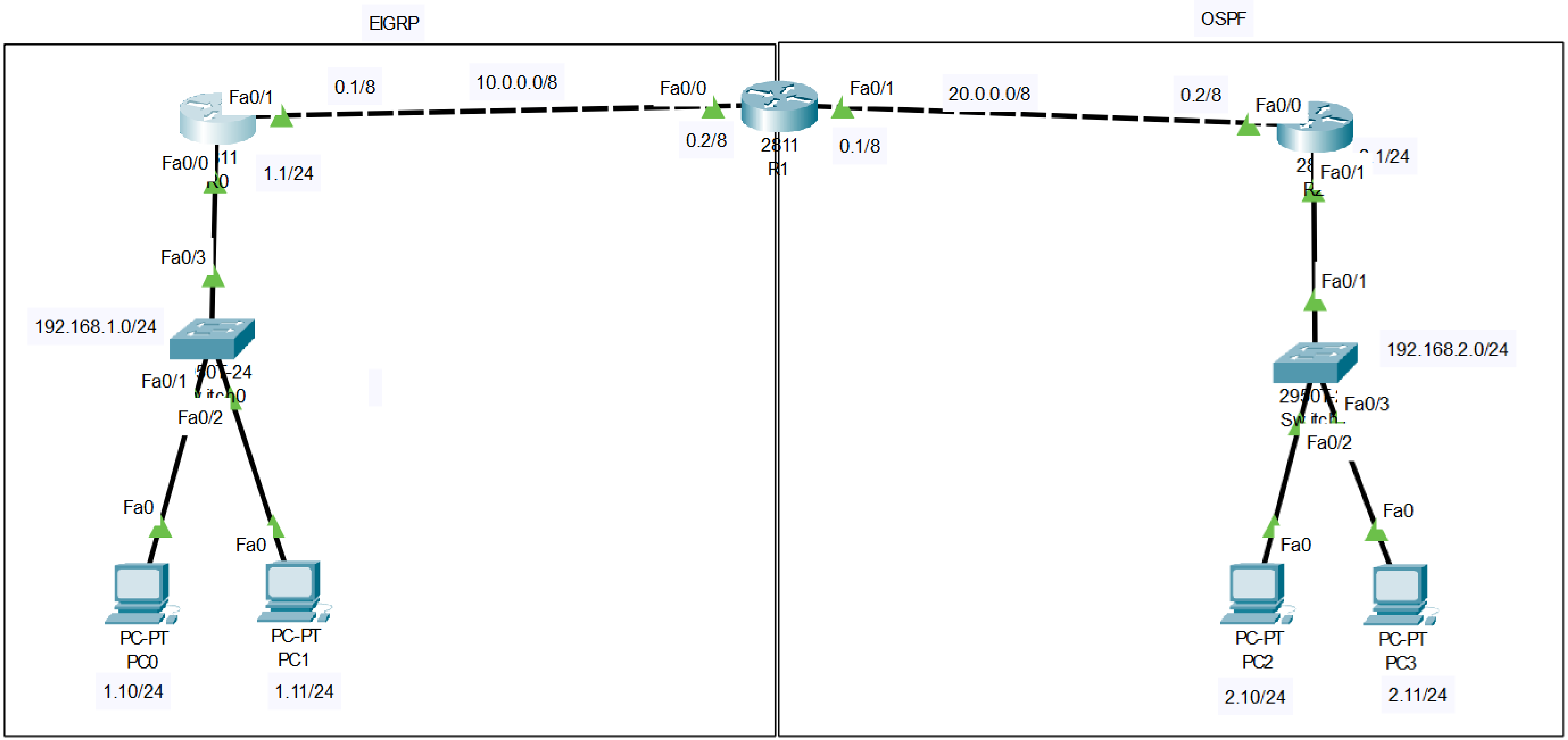
```
R1(config)#router rip
R1(config-router)#red
R1(config-router)#redistribute ei
R1(config-router)#redistribute eigrp 13 me
R1(config-router)#redistribute eigrp 13 metric ?
  <0-16>        Default metric
  transparent   Transparently redistribute metric
R1(config-router)#redistribute eigrp 13 metric 1
R1(config-router)#end
R1#
%SYS-5-CONFIG_I: Configured from console by console

R1#sho
R1#show ip rou
R1#show ip route
```

```
Gateway of last resort is not set

     10.0.0.0/8 is variably subnetted, 2 subnets, 2 masks
C       10.0.0.0/8 is directly connected, FastEthernet0/0
L       10.0.0.2/32 is directly connected, FastEthernet0/0
     20.0.0.0/8 is variably subnetted, 2 subnets, 2 masks
C       20.0.0.0/8 is directly connected, FastEthernet0/1
L       20.0.0.1/32 is directly connected, FastEthernet0/1
D    192.168.1.0/24 [90/30720] via 10.0.0.1, 00:13:59, FastEthernet0/0
R    192.168.2.0/24 [120/1] via 20.0.0.2, 00:00:19, FastEthernet0/1
```

VALIDATING ROUTES ON R2

```
R2#show 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 not set

R    10.0.0.0/8 [120/1] via 20.0.0.1, 00:00:19, FastEthernet0/0
     20.0.0.0/8 is variably subnetted, 2 subnets, 2 masks
C       20.0.0.0/8 is directly connected, FastEthernet0/0
L       20.0.0.2/32 is directly connected, FastEthernet0/0
R    192.168.1.0/24 [120/1] via 20.0.0.1, 00:00:19, FastEthernet0/0
     192.168.2.0/24 is variably subnetted, 2 subnets, 2 masks
C       192.168.2.0/24 is directly connected, FastEthernet0/1
L       192.168.2.1/32 is directly connected, FastEthernet0/1
```

REDISTRIBUTION ON EIGRP & OSPF



ON ROUTER R0:

```
R0>en
R0#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R0(config)#router eigrp 14
R0(config-router)#network 192.168.1.0
R0(config-router)#network 10.0.0.0
R0(config-router)#no auto-sum
R0(config-router)#no auto-summary
R0(config-router)#exit
```

ON ROUTER R1:

```
R1>en
R1#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R1(config)#router eigrp 14
R1(config-router)#network 10.0.0.0
R1(config-router)#
%DUAL-5-NBRCHANGE: IP-EIGRP 14: Neighbor 10.0.0.1 (FastEthernet0/0) is up: new adjacency

R1(config-router)#end
R1#
%SYS-5-CONFIG_I: Configured from console by console
```

Listing neighbours on R1:

```
R1#
R1#sh
R1#show ip ei
R1#show ip eigrp ne
R1#show ip eigrp neighbors
IP-EIGRP neighbors for process 14
H   Address         Interface      Hold Uptime    SRTT   RTO   Q    Seq
                                   (sec)          (ms)         Cnt  Num
0   10.0.0.1        Fa0/0          11   00:00:41  40     1000  0    1
```

CONFIGURING OSPF ON ROUTER R1

```
R1#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R1(config)#router ospf 1
R1(config-router)#network 20.0.0.0 0.255.255.255 area 0
R1(config-router)#exit
R1(config)#exit
R1#
%SYS-5-CONFIG_I: Configured from console by console
```

CONFIGURING OSPF ON ROUTER R2

```
R2>en
R2#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R2(config)#router ospf 1
R2(config-router)#network 20.0.0.0 0.255.255.255 area 0
R2(config-router)#network 192.168.2.0 0.0
00:09:00: %OSPF-5-ADJCHG: Process 1, Nbr 20.0.0.1 on FastEthernet0/0 from LOADING
R2(config-router)#netwo
R2(config-router)#network 192.168.2.0 0.0.0.255 area 1
R2(config-router)#end
R2#
%SYS-5-CONFIG_I: Configured from console by console
```

LISTING OSPF EXTERNAL ENTRY ON ROUTER R1:

```
R1#show 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 not set

     10.0.0.0/8 is variably subnetted, 2 subnets, 2 masks
C       10.0.0.0/8 is directly connected, FastEthernet0/0
L       10.0.0.2/32 is directly connected, FastEthernet0/0
     20.0.0.0/8 is variably subnetted, 2 subnets, 2 masks
C       20.0.0.0/8 is directly connected, FastEthernet0/1
L       20.0.0.1/32 is directly connected, FastEthernet0/1
D    192.168.1.0/24 [90/30720] via 10.0.0.1, 00:07:47, FastEthernet0/0
O IA 192.168.2.0/24 [110/2] via 20.0.0.2, 00:01:14, FastEthernet0/1
```

ON ROUTER R1, REDISTRIBUTING OSPF, UNDER EIGRP

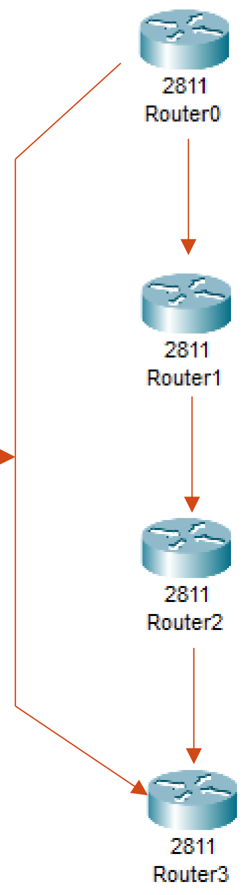
```
R1#
R1#router ei
R1#con
R1#conf t
R1#conf terminal
Enter configuration commands, one per line.  End with CNTL/Z.
R1(config)#
R1(config)#router ei
R1(config)#router eigrp 14
R1(config-router)#re
R1(config-router)#redistribute ospf 1 met
R1(config-router)#redistribute ospf 1 metric 1 1 255 255 1
R1(config-router)#exit
R1(config)#
```

ON ROUTER R1, REDISTRIBUTING EIGRP, UNDER OSPF

```
R1(config)#router ospf 1
R1(config-router)#red
R1(config-router)#redistribute eigrp 14 subnets
R1(config-router)#exit
R1(config)#^Z
R1#
%SYS-5-CONFIG_I: Configured from console by console
```

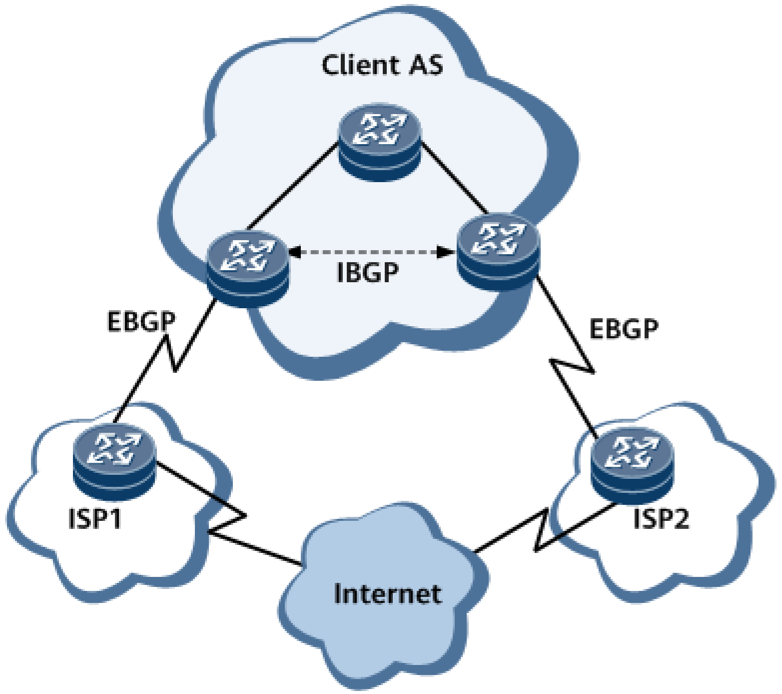
BORDER GATEWAY PROTOCOL (BGP-4)

- It's an inter-domain routing protocol.
- It uses a path-vector algorithm for best path selection.
- It uses TCP port 179 for connection establishment.
- Neighbors are explicitly defined.
- Before sending the packet from one network to another BGP will have 3-way handshake.



BORDER GATEWAY PROTOCOL (BGP-4)

- Public AS: 1 – 64511
- Private AS: 64512 – 65535
- There are many versions of BGP, such as:
  - BGP version 1: This version was released in 1989 and is defined in RFC 1105.
  - BGP version 2: It was defined in RFC 1163.
  - BGP version 3: It was defined in RFC 1267.
  - BGP version 4: It is the current version of BGP defined in RFC 1771.

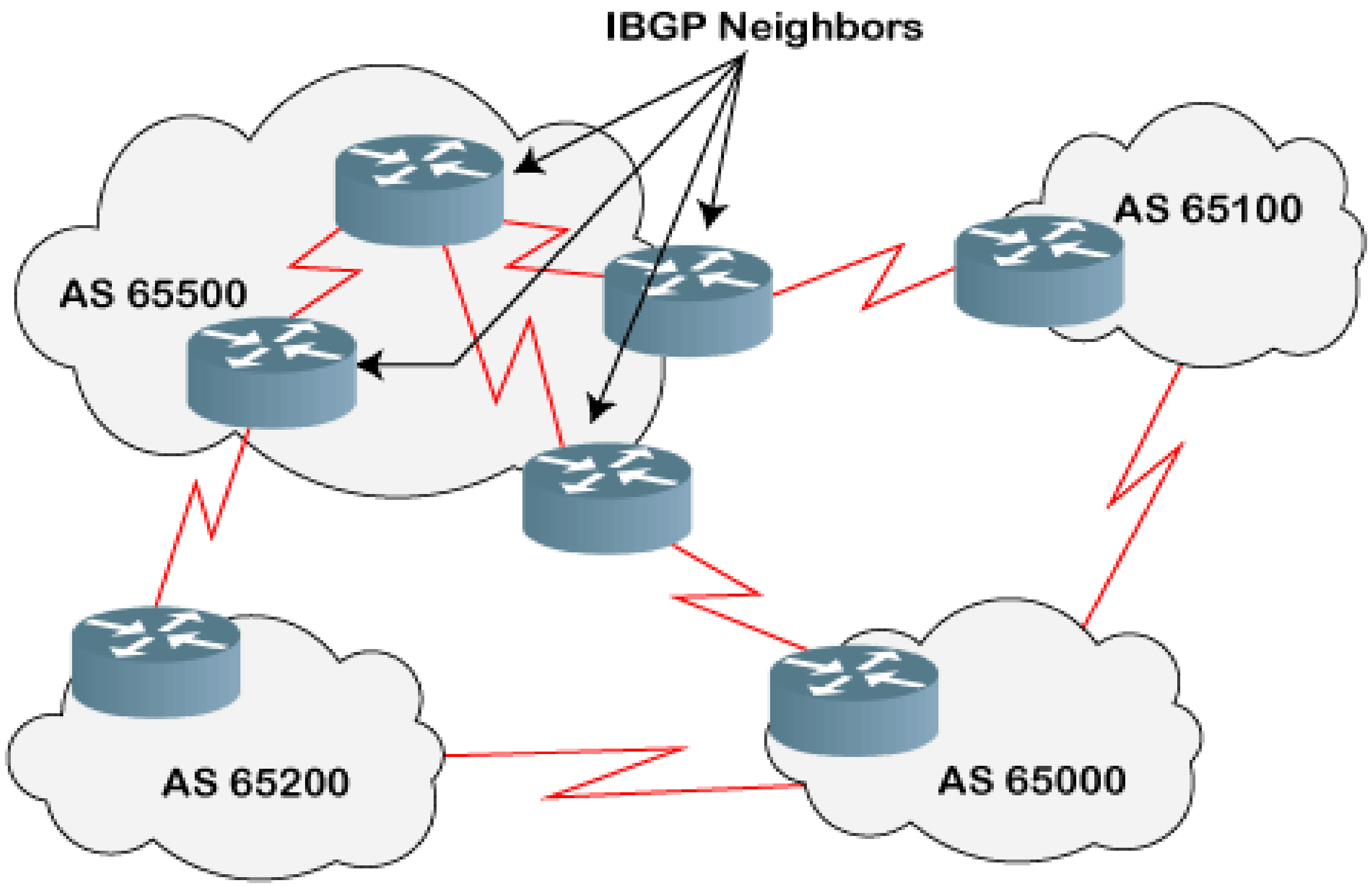


HOW BGP IS DIFFERENT?

- In IGP, you cannot configure neighbors explicitly.
- In BGP, you can even through they are not connect directly.
- Unlike, IGP, BGP advertise the whole subnet, instead of advertising the individual network.
- BGP can be configured
  - Within AS (IBGP)
  - In between AS (EBGP)

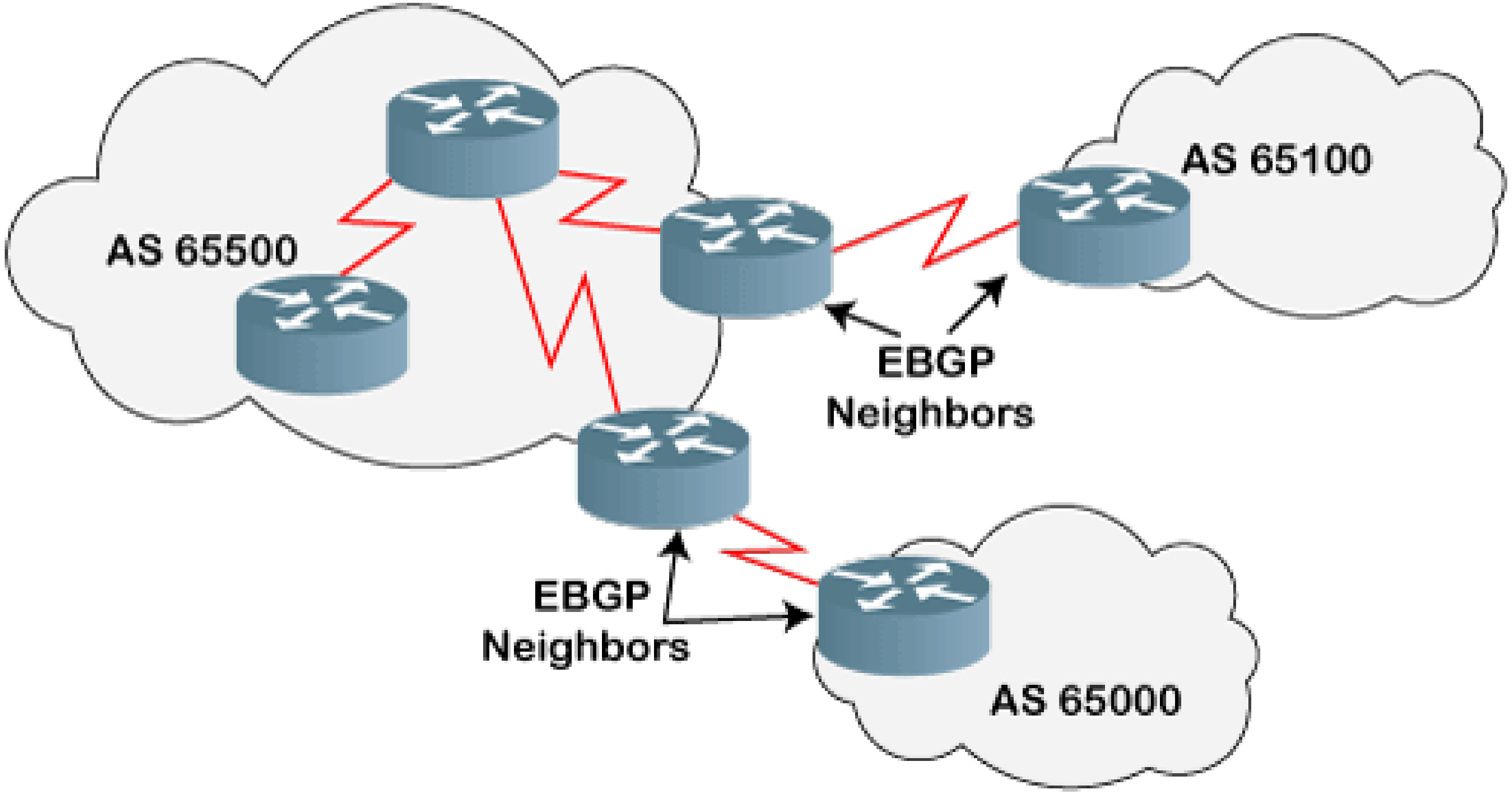
IBGP (INTERNAL BGP)

- If all the routers are neighbors of each other and belong to the same autonomous number system, the routers are referred to as an IBGP.



EBGP (EXTERNAL BGP)

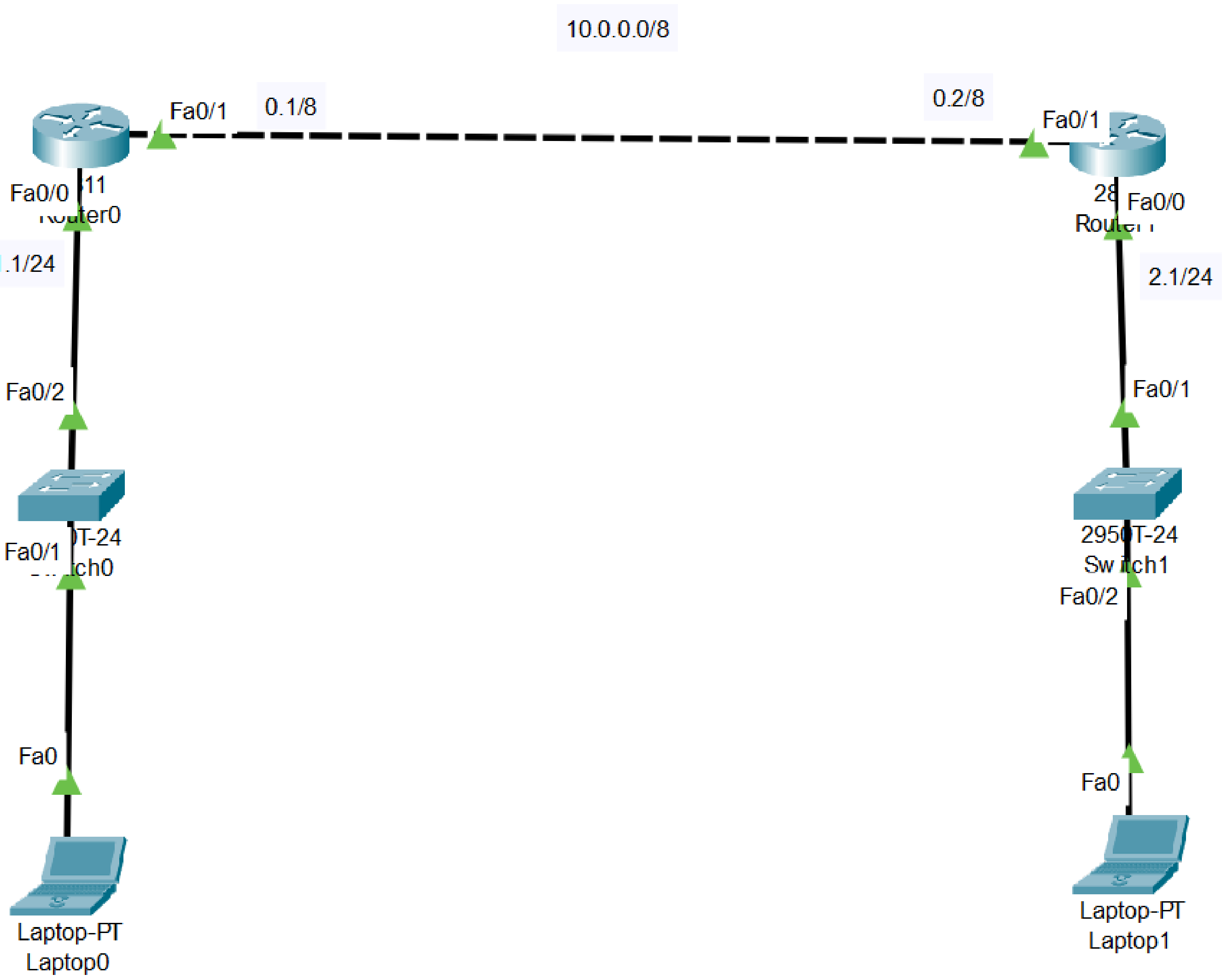
- If all the routers are neighbors of each other and they belong to the different autonomous number systems, then the routers are referred to as an EBGP.



TYPES OF PACKETS IN BGP

- Open
  - When one router wants to connect to another router and wants to create a neighborhood relation, it uses the open message.
- Update
  - It is used in two situations:
    - It is used to withdraw a destination that has been previously advertised.
    - It is also used to announce a route to a new destination.
- Keep Alive
  - Such a message is exchanged regularly.
  - It is used to tell other routers if they are alive or not.
  - For example, 'Hello' packets.
- Notification
  - It is sent by a router when there is an error condition.
  - It is also sent by the router when it wants to close a connection.

BORDER GATEWAY PROTOCOL - DEMO



ROUTER CONFIGURATION ON R0:

```
Router(config)#router ?
  bgp     Border Gateway Protocol (BGP)
  eigrp   Enhanced Interior Gateway Routing Protocol (EIGRP)
  ospf    Open Shortest Path First (OSPF)
  rip     Routing Information Protocol (RIP)
Router(config)#router bgp
Router(config)#router bgp ?
  <1-65535>  Autonomous system number
Router(config)#router bgp 300
Router(config-router)#network 192.168.1.0
Router(config-router)#network 10.0.0.0
Router(config-router)#neig
Router(config-router)#neighbor 10.0.0.2
% Incomplete command.
Router(config-router)#neighbor 10.0.0.2 remote-
Router(config-router)#neighbor 10.0.0.2 remote-as 400
Router(config-router)#neighbor 192.168.2.1 remote-as 400
Router(config-router)#exit
```

ROUTER CONFIGURATION ON R1:

```
Router(config)#router bgp 400
Router(config-router)#
Router(config-router)#network 10.0.0.0
Router(config-router)#network 192.168.2.0
Router(config-router)#neig
Router(config-router)#neighbor 10.0.0.1 remo
Router(config-router)#neighbor 10.0.0.1 remote-as 300
Router(config-router)#%BGP-5-ADJCHANGE: neighbor 10.0.0.1 Up

Router(config-router)#nei
Router(config-router)#neighbor 192.168.1.1 re
Router(config-router)#neighbor 192.168.1.1 remote-as 300
Router(config-router)#exit
```

DISPLAY PROTOCOL DETAILS ON ROUTER R0:

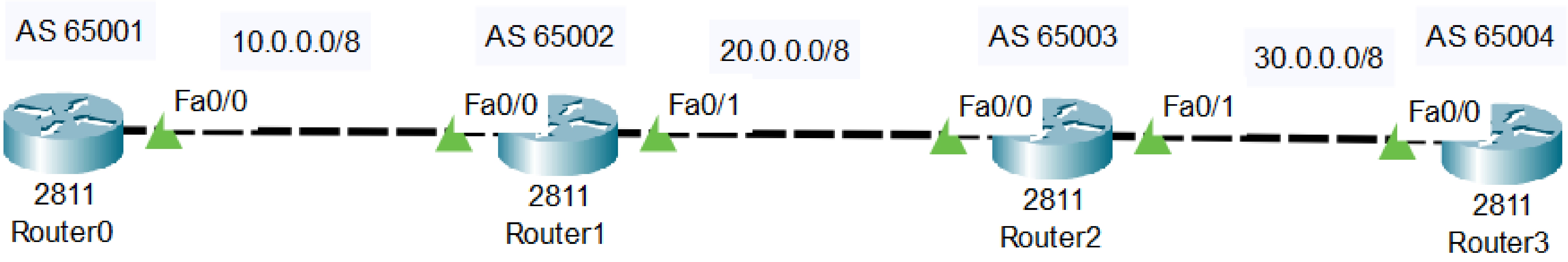
```
Router#show ip route
Codes: L - local, C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2, E - 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 not set

     10.0.0.0/8 is variably subnetted, 2 subnets, 2 masks
C       10.0.0.0/8 is directly connected, FastEthernet0/1
L       10.0.0.1/32 is directly connected, FastEthernet0/1
     192.168.1.0/24 is variably subnetted, 2 subnets, 2 masks
C       192.168.1.0/24 is directly connected, FastEthernet0/0
L       192.168.1.1/32 is directly connected, FastEthernet0/0
B    192.168.2.0/24 [20/0] via 10.0.0.2, 00:00:00
```

```
Router#show ip pro
Router#show ip protocols
Routing Protocol is "bgp 300"
  Outgoing update filter list for all interfaces is not set
```

DISPLAY PROTOCOL DETAILS ON ROUTER R1:

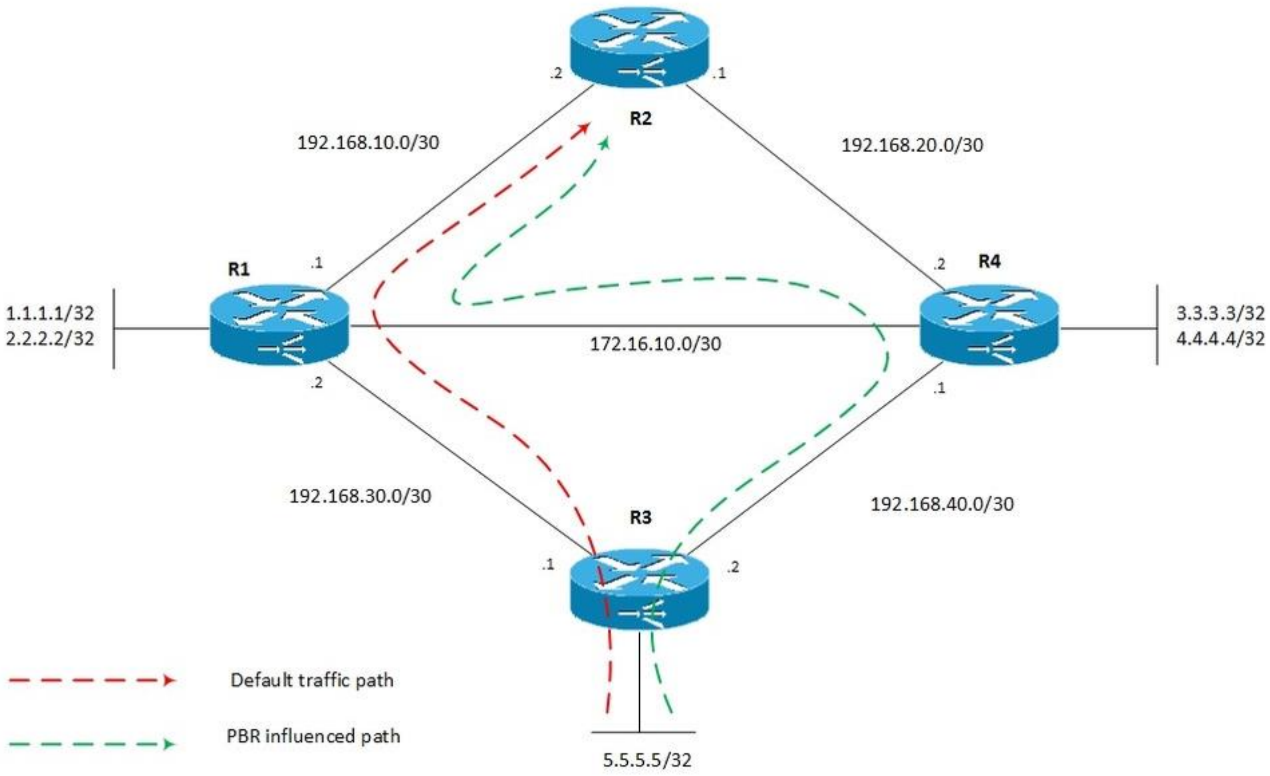
```
Router#show ip protocols
Routing Protocol is "bgp 400"
  Outgoing update filter list for all interfaces is not set
  Incoming update filter list for all interfaces is not set
  IGP synchronization is disabled
  Automatic route summarization is disabled
  Neighbor(s):
    Address          FiltIn FiltOut DistIn DistOut Weight RouteMap
    10.0.0.1
    192.168.1.1
  Maximum path: 1
    Routing Information Sources:
      Gateway         Distance      Last Update
      10.0.0.1              20          00:00:00
    Distance: external 20 internal 200 local 200
```

BGP TASK


AS 65001
10.0.0.0/8
AS 65002
20.0.0.0/8
AS 65003
30.0.0.0/8
AS 65004
Fa0/0
Fa0/0
Fa0/1
Fa0/0
Fa0/1
Fa0/0
2811
Router0
2811
Router1
2811
Router2
2811
Router3

POLICY BASED ROUTING (PBR)

- PBR forces specific traffic over a specific path.
- PBR could over-ride the default behavior of working on a specific router.
- To implement PBR:
  1. Create an ACL to define the traffic that should be based on PBR.
  2. Create route map (if/then) statement.
  3. Apply the route map to the interface.



POLICY BASED ROUTING (PBR)

- Allows network administrators to override traditional routing decisions based on policies rather than solely on destination IP addresses.
- Enables fine-grained control over traffic paths, allowing prioritization of specific traffic flows or bypassing of certain paths.
- Can be used to distribute traffic across multiple paths, ensuring better utilization of available resources.
- Typically configured on routers and Layer 3 switches through access control lists (ACLs) and route maps.
- PBR allows forwarding decision based on:
  - Source IP address
  - Destination IP address
  - Protocol Type (HTTP, HTTPS, etc.)

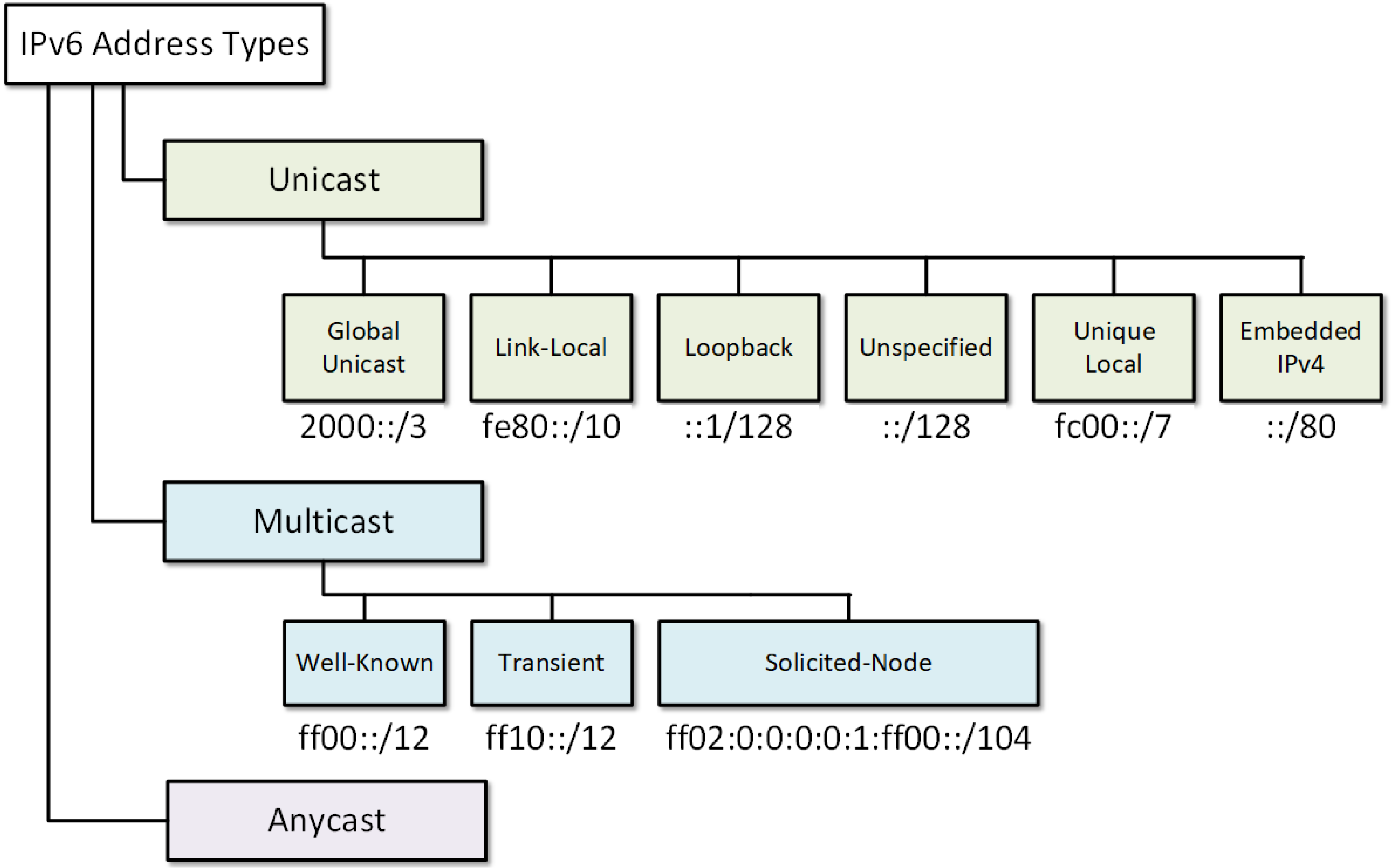
IPV6

- IPv6 is the next-generation Internet Protocol, designed to replace IPv4, which is running out of available addresses.
- IPv6 uses 128-bit addresses, allowing for approximately 340 undecillion (3.4 x 10^38) unique addresses, compared to the 32-bit addressing system in IPv4, which supports about 4.3 billion addresses.
- IPv6 addresses are written in eight groups of four hexadecimal digits, separated by colons (e.g., 2001:0db8:85a3:0000:0000:8a2e:0370:7334).
- Due to its vast address space, IPv6 eliminates the need for Network Address Translation.
- IPv6 includes IPsec as a mandatory feature, providing better support for encryption, authentication, and secure data transmission.

IPV4 VS IPV6

	Ipv4	Ipv6
Address length	IPv4 is a 32-bit address.	IPv6 is a 128-bit address.
Fields	IPv4 is a numeric address that consists of 4 fields which are separated by dot (.).	IPv6 is an alphanumeric address that consists of 8 fields, which are separated by colon.
Classes	IPv4 has 5 different classes of IP address that includes Class A, Class B, Class C, Class D, and Class E.	IPv6 does not contain classes of IP addresses.
Number of IP address	IPv4 has a limited number of IP addresses.	IPv6 has a large number of IP addresses.
VLSM	It supports VLSM (Virtual Length Subnet Mask). Here, VLSM means that Ipv4 converts IP addresses into a subnet of different sizes.	It does not support VLSM.
Address configuration	It supports manual and DHCP configuration.	It supports manual, DHCP, auto-configuration, and renumbering.
Address space	It generates 4 billion unique addresses	It generates 340 undecillion unique addresses.

IPV6 ADDRESS TYPES



IPV6 ADDRESS TYPES

- Unicast address
  - The unicast address specifies a single interface. A packet sent to a unicast address destination travels from one host to the destination host.
  - Types of unicast addresses:
    - Link-Local address
      - Link-local addresses are designed for use on a single local link (local network).
      - Link-local addresses are automatically configured on all interfaces.
      - The prefix used for a link-local address is fe80::/10.
    - Global address
      - Global addresses are designed for use on any network. The prefix used for a global address begins with binary 001.

IPV6 ADDRESS TYPES

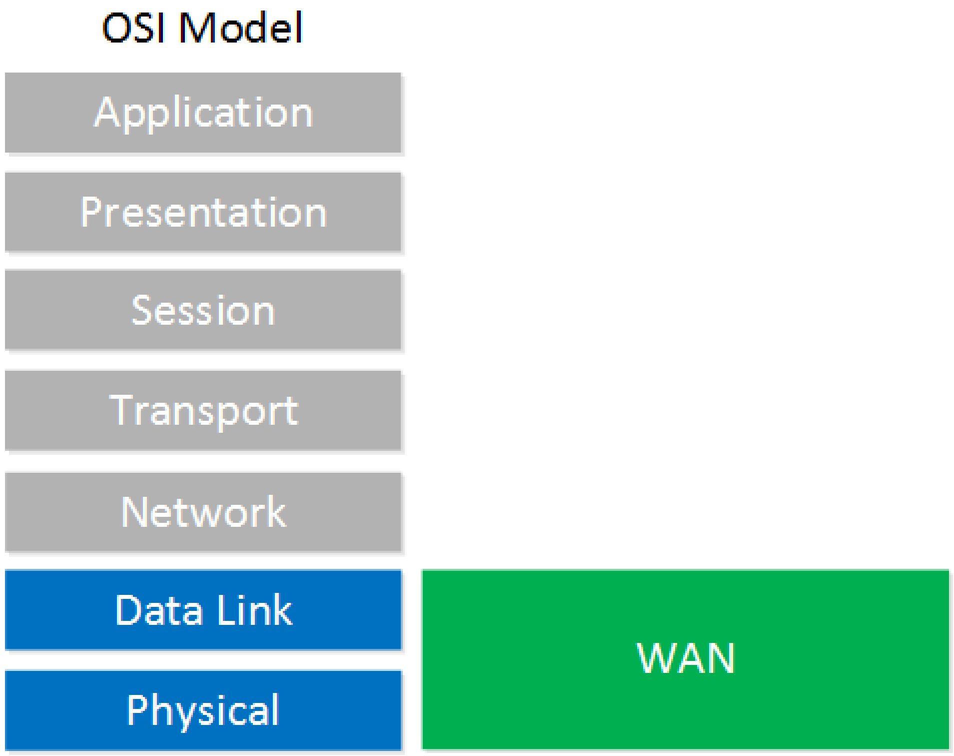
- Special types of unicast addresses:
  - Unspecified address
    - The unspecified address is 0:0:0:0:0:0:0:0.
    - You can abbreviate the address with two colons (::).
    - The unspecified address indicates the absence of an address, and it can never be assigned to a host.
  - Loopback address
    - The loopback address is 0:0:0:0:0:0:0:1.
    - You can abbreviate the address as ::1.
    - The loopback address is used by a node to send a packet to itself.

IPV6 ADDRESS TYPES

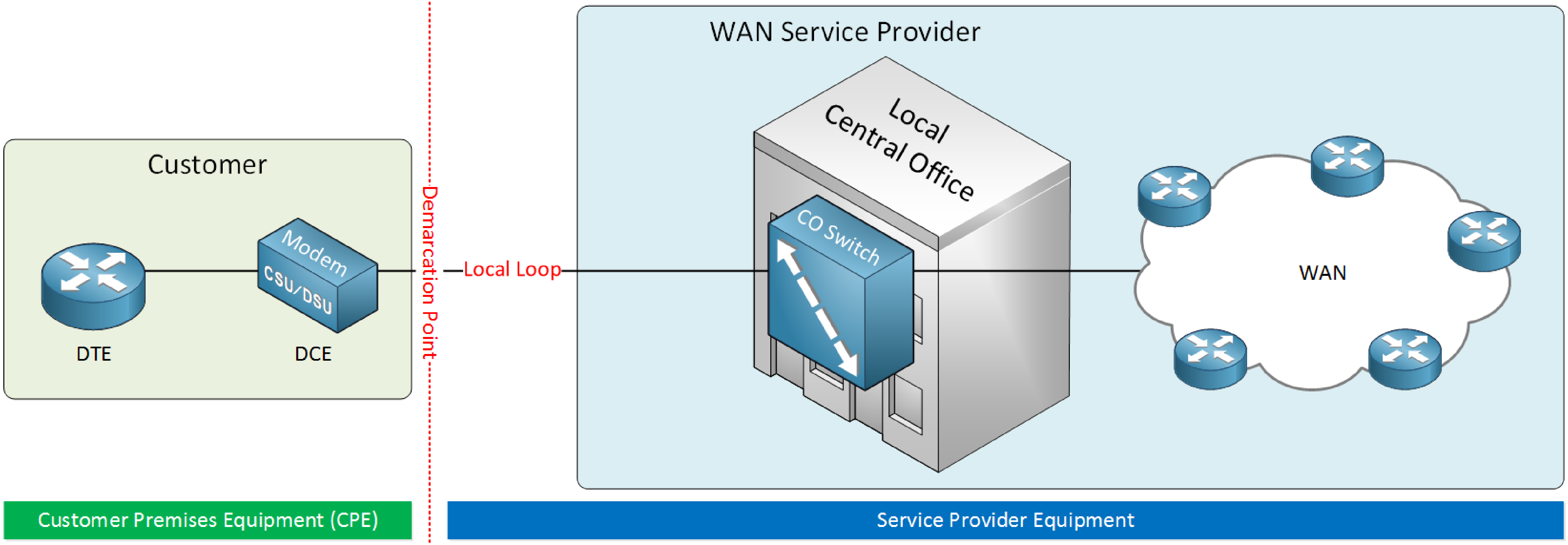
- Anycast address
  - An anycast address specifies a set of interfaces, possibly at different locations, that all share a single address.
- Multicast address
  - The multicast address specifies a set of interfaces, possibly at multiple locations.
  - The prefix used for a multicast address is ff.
  - If a packet is sent to a multicast address, one copy of the packet is delivered to each member of the group.

WIDE-AREA NETWORK

- A wide-area network (WAN) is a collection of local-area networks (LANs) or other networks that communicate with one another.
- A WAN is essentially a network of networks, with the Internet the world's largest WAN.
- WAN links define a new type of L1 & L2 connectivity.
- Allows links to the internet or other offices.



WAN TERMINOLOGY



WAN TERMINOLOGY

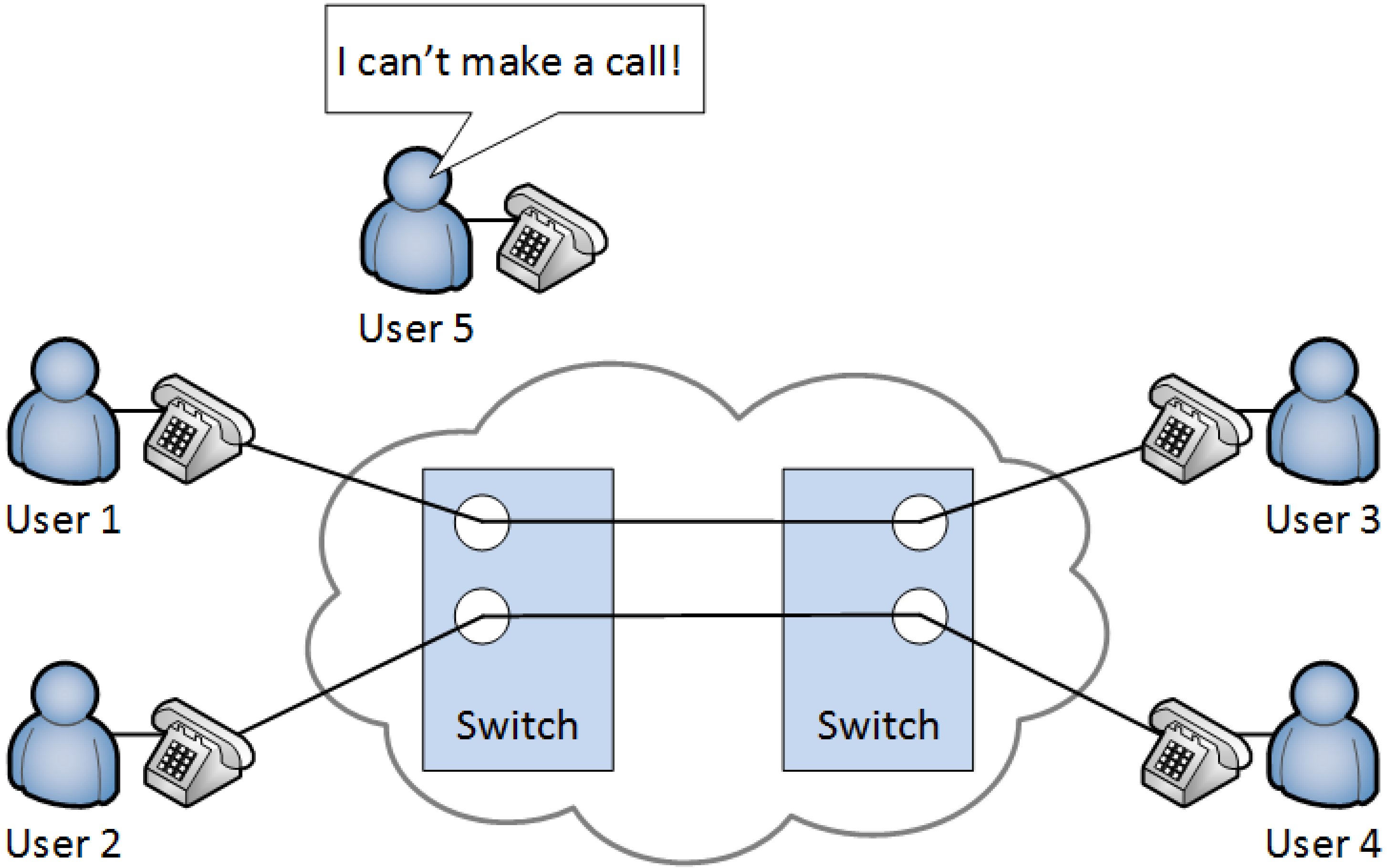
- CPE (Customer Premises Equipment) are all devices, wiring, and hardware that are located at the site of the customer.
- Demarcation point (demarc) is where the service provider's wiring ends and where the customer's wiring begins.
- DTE (Data Terminal Equipment) is the customer device that forwards data from the customer's network to the WAN. This can be a router, computer or sometimes a switch.
- CSU/DSU (Channel Service Unit / Data Service Unit)
  - is a device that sits in between the router and WAN connection.
  - It converts digital signals from the WAN into a digital signal the router understands and vice versa.

WAN TERMINOLOGY

- DCE (Data Circuit-terminating Equipment)
  - is the device that receives data from the DTE, modulates into an analog signal and forwards it onto the wire to the service provider.
  - It also demodulates analog signals that it receives on the wire into digital signals.
- Local loop is the physical link that connects from the demarcation point at the customer to the edge of the service provider network.
- CO (Central Office) is the building where all lines from local loops to the customers end up.

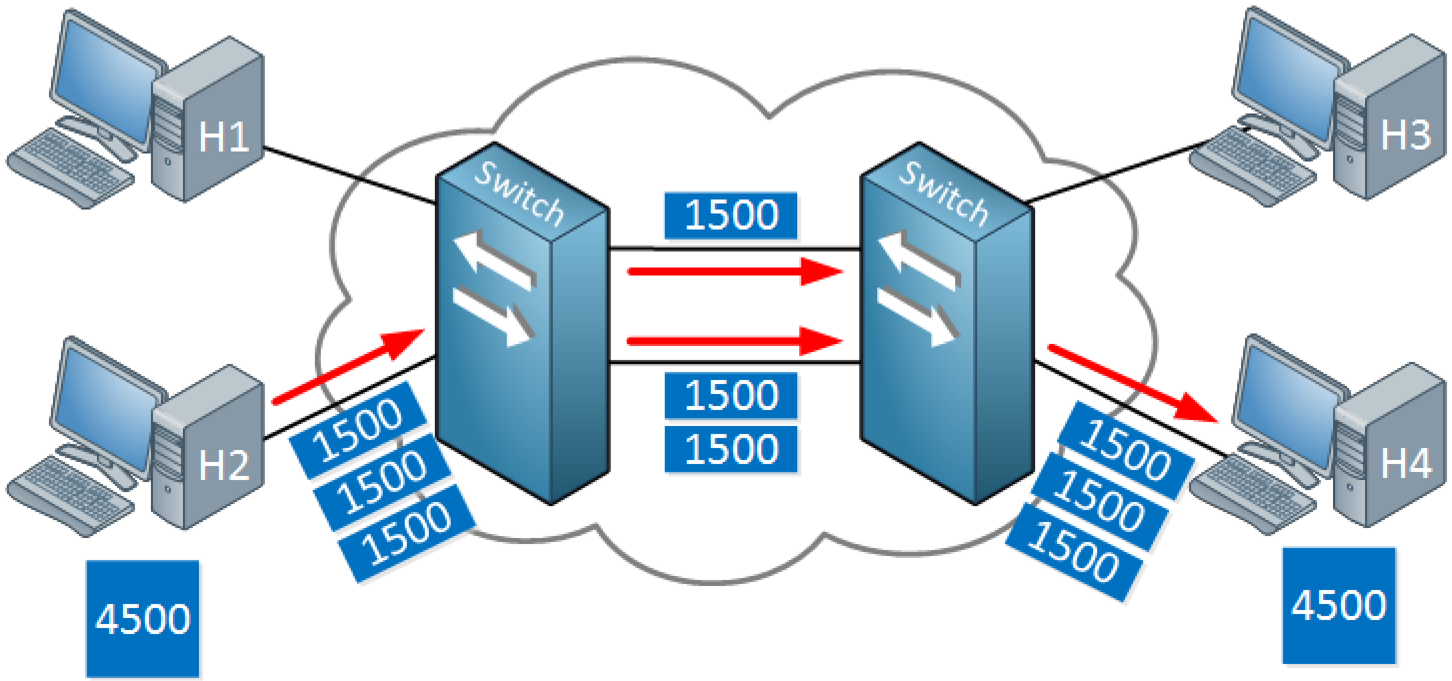
WAN TECHNOLOGIES

- There are a number of different methods how we can forward data on a network:
  - Circuit switching



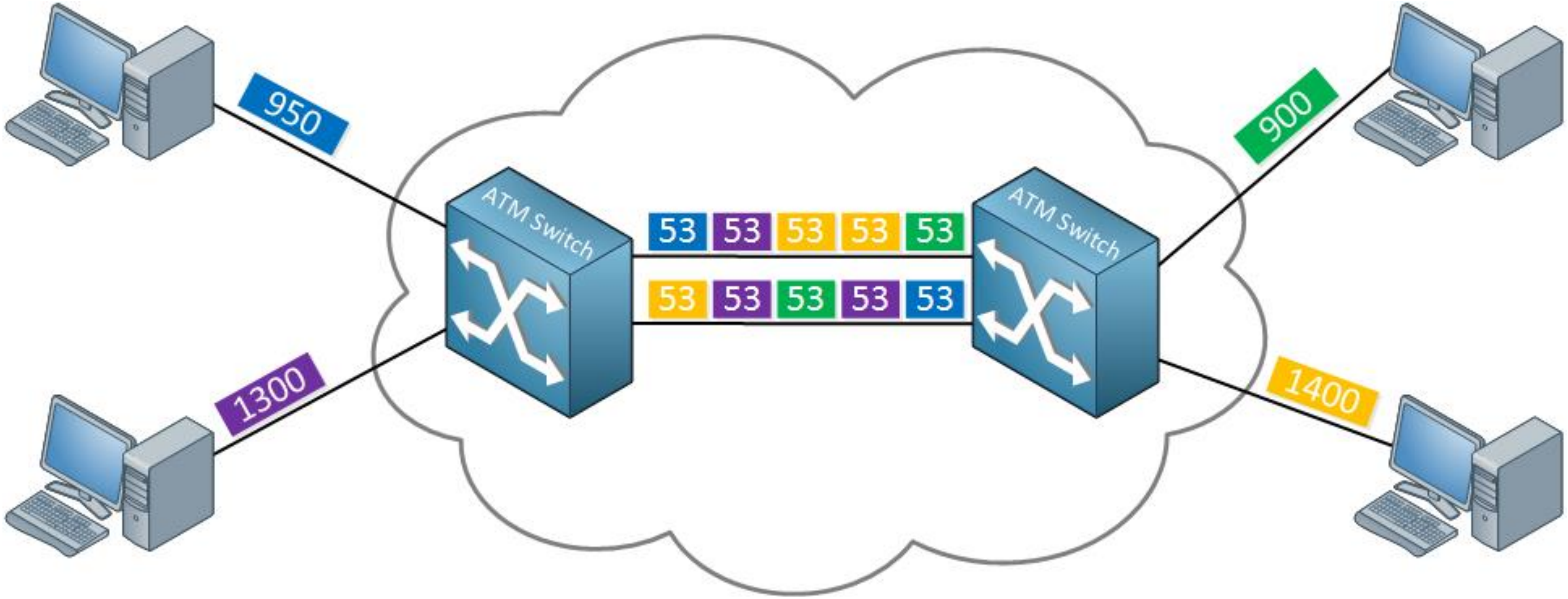
WAN TECHNOLOGIES

- There are a number of different methods how we can forward data on a network:
  - Packet switching
    - The idea behind it is that we break our data down in “chunks”. Each chunk is a packet that is sent on the network. This is what we mostly use on our networks nowadays.



WAN TECHNOLOGIES

- There are a number of different methods how we can forward data on a network:
  - Cell switching
    - Cell switching is very similar to packet switching with the exception that we use a fixed for our size for our cells.



OTHER TYPES OF WAN TECHNOLOGIES

- TCP/IP protocol suite
- Router
- Overlay network
- Packet over SONET/SDH (PoS)
- Multiprotocol Label Switching (MPLS)
- ATM (Asynchronous Transfer Mode)
- Frame Relay

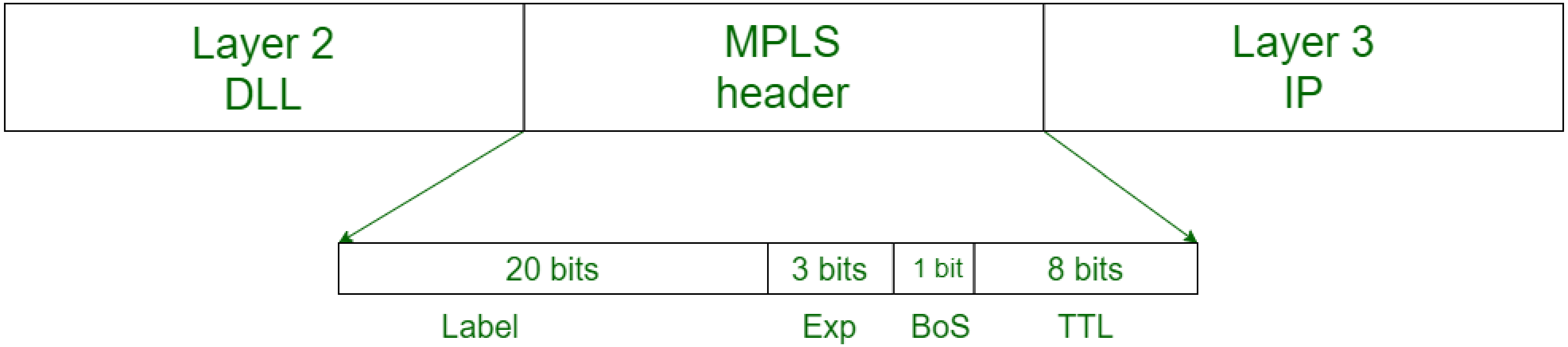
MULTI PROTOCOL LABEL SWITCHING (MPLS)

- MPLS is an IP packet routing technique that routes IP packet through paths via labels instead of looking at complex routing tables of routers.
- This feature helps in increasing the delivery rate of IP packets.
- MPLS uses layer 3 service i.e, Internet Protocol, and uses router as forwarding device.
- The traffic of different customers is separated from each other because MPLS works somewhat like VPN.
- An MPLS header is added to packet that lies between layers 2 and 3. Hence, it is also considers to be Layer 2.5 protocol.

MPLS HEADER

The MPLS Header is 32 bit long and is divided into four parts –

1. Label – This field is 20 bit long and can take value b/w 0 & 220 – 1.
2. Exp – They are 3 bits long and used for Quality of Service(QoS).
3. Bottom of stack (S) – It is of size 1 bit. MPLS labels are stacked one over other. If there is only one label remained in MPLS header, then its value is 1 otherwise 0.
4. Time to Live (TTL) – It is 8 bit long and its value is decreased by one at each hop to prevent packet to get stuck in network.



IMPORTANT TERMS

- Provider Edge(PE) Router - Router at edge of MPLS network that add or remove label from IP packet.
- Customer Edge(CE) Router - Router at edge of customer network that send or receive IP packet from PE.
- Label Switch Router(LSR) - Routers used in MPLS network that can understand labels.
- Ingress LSR - LSR routers that receive IP packet from CE Routers and add MPLS header.
- Intermediate LSR - LSR routers that swap label in MPLS header and assigned for forwarding labeled IP packet.
- Egress LSR - LSR routers that send IP packet to CE routers and removes MPLS header.
- Push, Pop and Swap - Action of addition, removal and swapping of labels by LSR respectively.

TRANSMISSION

- Transmission is the action of transferring or moving something from one position or person to another. It is a mechanism of transferring data between two devices connected using a network. It is also called communication Mode.
- In computer networking there are two types of Transmission:
  - Synchronous transmissions
  - Asynchronous transmissions

SYNCHRONOUS TRANSMISSION

- Synchronous data transmission is a data transfer method in which is a continuous stream of data signals accompanied by timing signals.
- It helps to ensure that the transmitter and the receiver are synchronized with each other.
- This communication methods is mostly used when large amounts of data needs to be transferred from one location to the other.

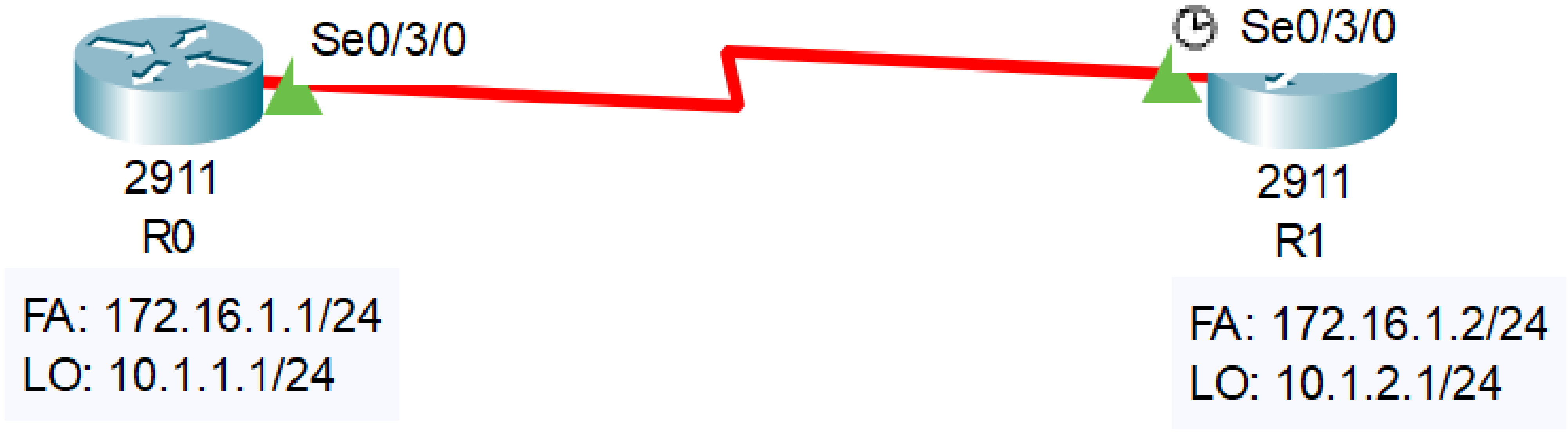
ASYNCHRONOUS TRANSMISSION

- Asynchronous Transmission is also known as start/stop transmission, sends data from the sender to the receiver using the flow control method.
- It does not use a clock to synchronize data between the source and destination.
- This transmission method sends one character or 8 bits at a time.
- In this method, before the transmission process begins, each character sends the start bit.
- After sending the character, it also sends the stop bit.
- With the character bits and start and stop bits, the total number of bits is 10 bits.

SYNCHRONOUS VS ASYNCHRONOUS TRANSMISSION

Synchronous Transmission	Asynchronous Transmission
It sends data in the form of blocks or frames.	Data is sent in the form of character or byte.
Synchronous Transmission is fast.	Asynchronous transmission method is slow.
Synchronous Transmission is costly.	Asynchronous Transmission is economical.
The time interval of transmission is constant.	The time interval of transmission is random.
does not have a gap between data.	there is a gap between data.
It does not need any local storage at the terminal end.	It requires local buffer storages at the two ends of the line to assemble blocks.

WAN – PPP CONNECTION



WAN – PPP CONNECTION – R0

```
Router#show ip int br
Interface              IP-Address      OK? Method Status                Protocol
FastEthernet0/0        unassigned      YES unset  administratively down down
FastEthernet0/1        unassigned      YES unset  administratively down down
Vlan1                  unassigned      YES unset  administratively down down
Router#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
```

```
Router(config)#int loopback 0

Router(config-if)#
%LINK-5-CHANGED: Interface Loopback0, changed state to up

%LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback0, changed state to up

Router(config-if)#ip add 10.1.1.1 255.255.255.0
Router(config-if)#no shut
Router(config-if)#exit
Router(config)#
Router(config)#int f
Router(config)#int fastEthernet 0/0
Router(config-if)#ip addr 172.16.1.1 255.255.255.0
Router(config-if)#no shut

Router(config-if)#
%LINK-5-CHANGED: Interface FastEthernet0/0, changed state to up

Router(config-if)#exit
```

WAN – PPP CONNECTION – R1

```
Router>en
Router#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
Router(config)#int lo
Router(config)#int loopback 0

Router(config-if)#
%LINK-5-CHANGED: Interface Loopback0, changed state to up

%LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback0, changed state to up

Router(config-if)#ip add 10.1.2.1 255.255.255.0
Router(config-if)#no shut
Router(config-if)#exit
Router(config)#int fa0/0
Router(config-if)#ip add 172.16.1.2 255.255.255.0
Router(config-if)#no shut

Router(config-if)#
%LINK-5-CHANGED: Interface FastEthernet0/0, changed state to up

%LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet0/0, changed state to up

Router(config-if)#exit
```

WAN – PPP CONNECTION – R1

```
Router#sh ip int br
Interface              IP-Address      OK? Method Status                Protocol
FastEthernet0/0        172.16.1.2      YES manual up                    up
FastEthernet0/1        unassigned      YES unset  administratively down down
Loopback0              10.1.2.1        YES manual up                    up
Vlan1                  unassigned      YES unset  administratively down down
Router#ping 172.16.1.1

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 172.16.1.1, timeout is 2 seconds:
.!!!!
Success rate is 80 percent (4/5), round-trip min/avg/max = 0/0/0 ms
```

SOFTWARE-DEFINED NETWORKING (SDN)

- SDN is an approach to networking that uses software-based controllers or application programming interfaces (APIs) to communicate with underlying hardware infrastructure and direct traffic on a network.
- This model differs from that of traditional networks, which use dedicated hardware devices (i.e., routers and switches) to control network traffic.
- SDN can create and control a virtual network – or control a traditional hardware – via software.
- Software-Defined Networking enables a new way of controlling the routing of data packets through a centralized server.

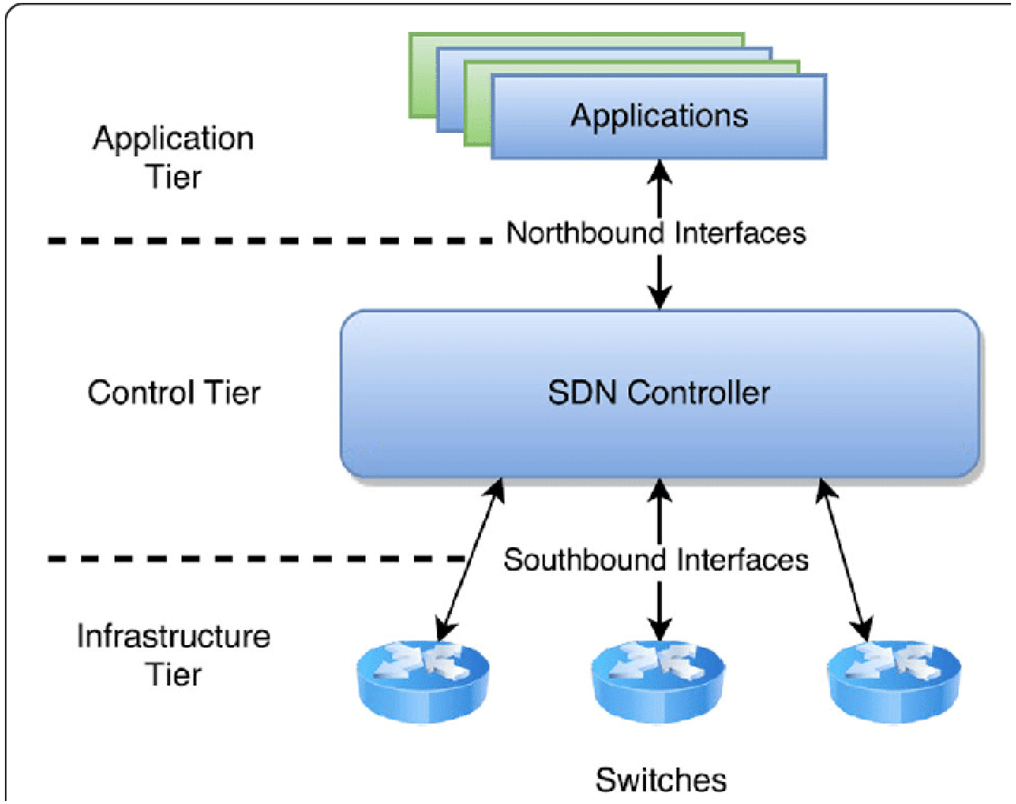
WHY SDN IS IMPORTANT?

- Increased control with greater speed and flexibility
  - You can control the flow of traffic over a network simply by programming an open standard software-based controller.
- Customizable network infrastructure
  - You can configure network services and allocate virtual resources to change the network infrastructure in real time through one centralized location.
- Robust security
  - A software-defined network delivers visibility into the entire network, providing a more holistic view of security threats.

HOW DOES SDN WORK?

There are three parts to a typical SDN architecture, which may be located in different physical locations:

- Applications, which communicate resource requests or information about the network as a whole
- Controllers, which use the information from applications to decide how to route a data packet
- Networking devices, which receive information from the controller about where to move the data



DIFFERENT MODELS OF SDN?

- Open SDN
  - Network administrators use a protocol like OpenFlow to control the behavior of virtual and physical switches at the data plane level.
- SDN by APIs
  - APIs control how data moves through the network on each device.
- SDN Overlay Model
  - It runs a virtual network on top of an existing hardware infrastructure, creating dynamic tunnels to different on-premise and remote data centers.
- Hybrid SDN
  - his model combines software-defined networking with traditional networking protocols in one environment to support different functions on a network.