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<u>LAB 6</u>

IP Routing

Objective:

1. To understand the basic concept of IP routing.
2. To configure, verify and troubleshoot Static and Dynamic Rouging

Aparatus: Packet Tracer

Theory:

Routing:

- The term router and layer 3 device are interchangeable.
- Routers use routing protocols to dynamically find all networks within the greater internetwork and to ensure that all routers have the same routing table.
- Routing protocols are also employed to determine the best path a packet should take through an internetwork to get to its destination most efficiently.
- RIP, RIPv2, EIGRP, and OSPF are great examples of the most common routing protocols.
- Once all routers know about all networks, a routed protocol can be used to send user data (packets) through the established enterprise. Routed protocols are assigned to an interface and determine the method of packet delivery. Examples of routed protocols are IP and IPv6.

- Once you create an internetwork by connecting your WANs and LANs to a router, you'll need to configure logical network addresses, like IP addresses, to all hosts on that internet work for them to communicate successfully throughout it.
- The term ***routing*** refers to taking a packet from one device and sending it through the network to another device on a different network. Routers don't really care about hosts they only care about networks and the best path to each

one of them. The logical network address of the destination host is key to get packets through a routed network.

- It’s the hardware address of the host that’s used to deliver the packet from a router and ensure it arrives at the correct destination host.
- A router must know the following minimum factors to able to effectively route packets:
  - Destination address
  - Neighbor routers from which it can learn about remote networks
  - Possible routes to all remote networks
  - The best route to each remote network
  - How to maintain and verify routing information

- The router learns about remote networks from neighboring routers or from an administrator. The router then builds a ***routing table***, which is basically a map of the internetwork, and it describes how to find remote networks. If a network is directly connected, then the router already knows how to get to it.
- But if a network isn’t directly connected to the router, the router must use one of two ways to learn how to get to the remote network. The ***static routing*** method requires someone to hand-type all network locations into the routing table, which can be a pretty daunting task when used on all but the smallest of networks!
- Conversely, when ***dynamic routing*** is used, a protocol on one router communicates with the same protocol running on neighboring routers. The routers then update each other about all the networks they know about and place this information into the routing table. If a change occurs in the network, the dynamic routing protocols automatically inform all routers about the event. If static routing is used, the administrator is responsible for updating all changes by hand onto all routers. Most people usually use a combination of dynamic and static routing to administer a large network.

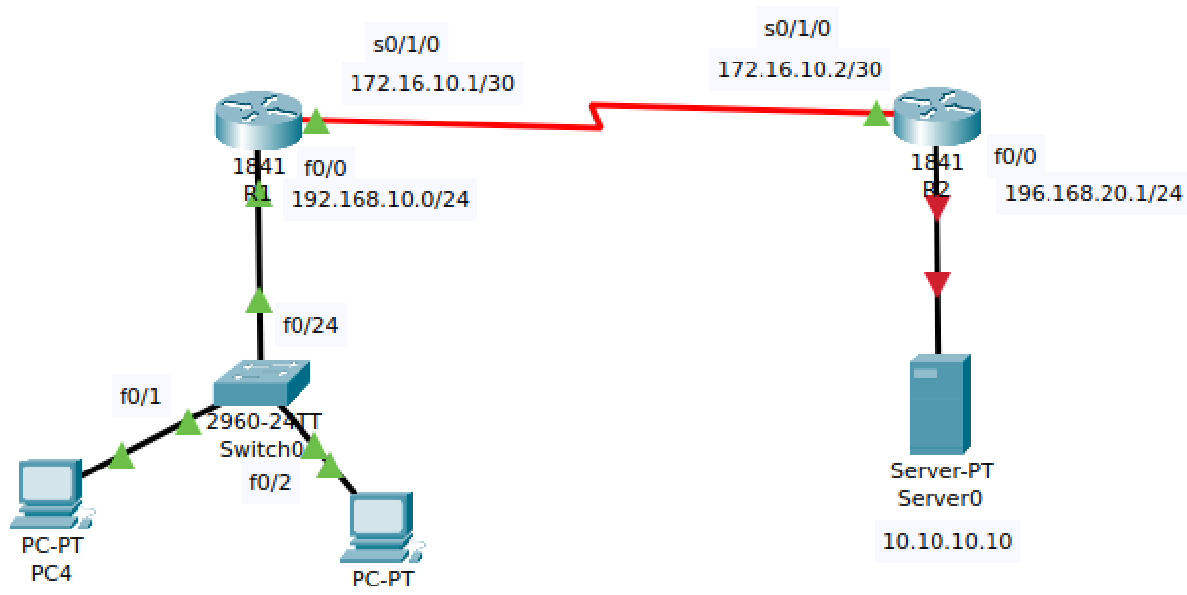


Figure 1: A LAN topology

Task 1:
Draw a LAN topology as shown in Figure 1 and interface the router and assign ip to the hosts. Then perform:

R1#show ip route
R2# show ip route

i. What outcome do you observe? What is the meaning of C in routing table?

R1#show ip arp

ii. What do you mean by dash(-) in output?
iii. Open command prompt of PC4 and do and observe the outputs of each.
C:\> ping 192.168.10.1
C:\> ping 172.16.10.1
C:\>arp -a

Types of Routing Algorithm
There are three types of routing:
1. Static routing
2. default routing
3. dynamic routing

Static Routing
Static routing is the process that ensues when you manually add routes in each router's routing table.

Syntax:
ip route [destination_network] [mask] [next-hop_address or exitinterface] [administrative_distance] [permanent]

This list describes each command in the string:
ip route : The command used to create the static route. destination_network.

mask: The network you're placing in the routing table. The subnet mask being used on the network.

next-hope_address: This is the IP address of the next-hop router that will receive packets and forward them to the remote network, which must signify a router interface that's on a directly connected network. You must be able to successfully ping the router interface before you can add the route. Important note to self is that if you type in the wrong next hop address or the interface to the correct router is down, the static route will show up in the router's configuration but not in the routing table.

exitinterface: Used in place of the next-hop address if you want, and shows up as a directly connected route.

administrative_distance: By default, static routes have an administrative distance of 1 or 0 if you use an exit interface instead of a next-hop address. You can change the default value by adding an administrative weight at the end of the command. I'll talk a lot moreabout this later in the chapter when we get to the section on dynamic routing.

permanent : If the interface is shut down or the router can't communicate to the next-hop router, the route will automatically be discarded from the routing table by default. Choosing the permanent option keeps the entry in the routing table no matter what happens.

<u>Example</u>: Static routing can be done in one of the **<u>three ways</u>**.
Router(config)#ip route 172.16.3.0 255.255.255.0 192.168.2.4

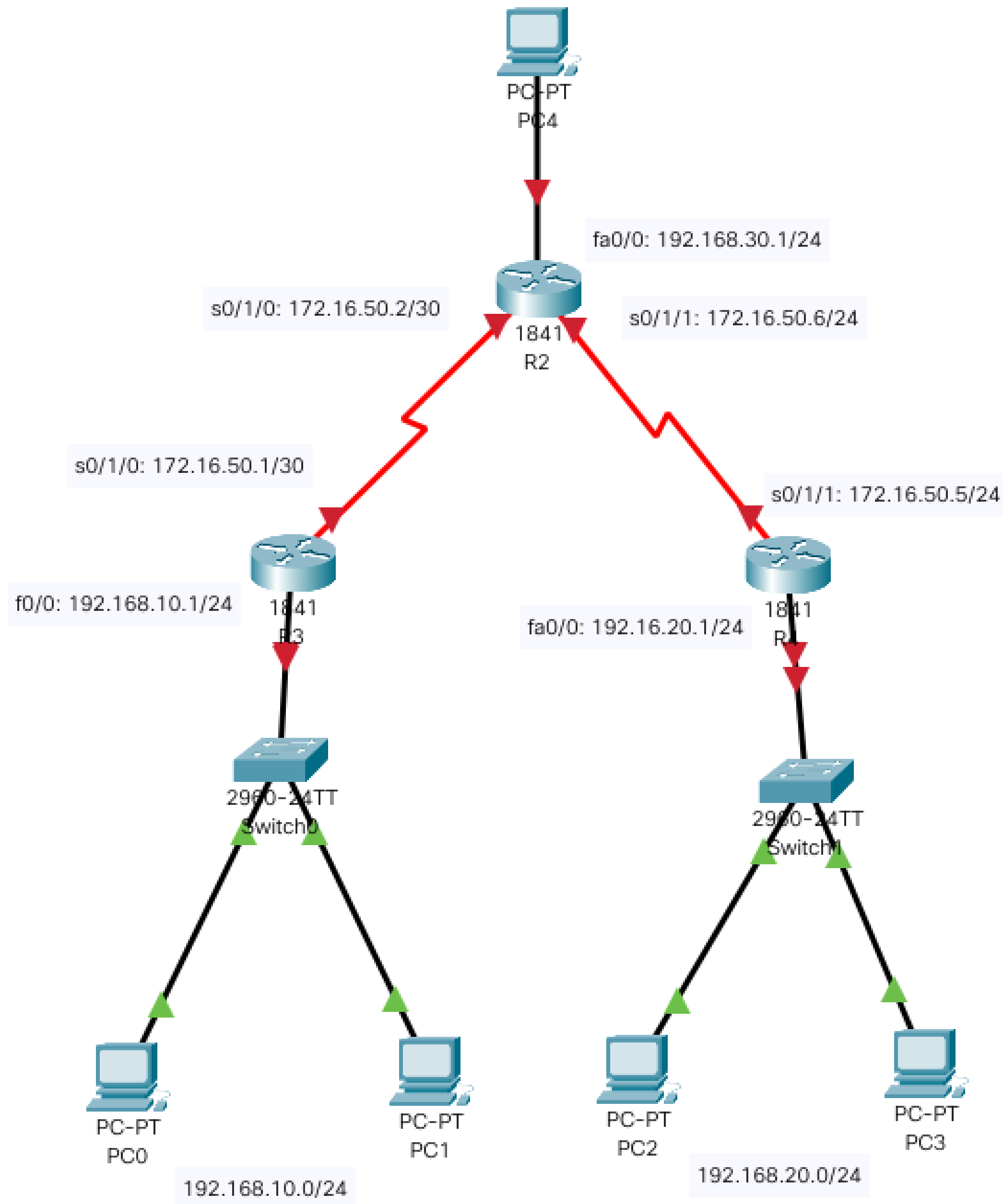
- The ip route command tells us simply that it's a static route.
- 172.16.3.0 is the remote network we want to send packets to.
- 255.255.255.0 is the mask of the remote network.
- 192.168.2.4 is the next hop, or router, that packets will be sent to.

Router(config)#ip route 172.16.3.0 255.255.255.0 192.168.2.4 *150*

The 150 at the end changes the default administrative distance (AD) of 1 to 150. AD is the trustworthiness of route, where 0 is best and 255 is worst.

Router(config)#ip route 172.16.3.0 255.255.255.0 *s0/1/0*

Instead of using a next-hop address, we can use an exit interface that will make the route up as a directly connected network. Functionally, the next hop and exit interface work exactly the same.



R3 Configuration

Router>enable
Router#configure terminal
Router#config)#hostname R3
R3(config)#interface f0/0

R3(config-if)#ip address 192.168.10.1 255.255.255.0
R3(config-if)#no shutdown
R3(config-if)#description Connection to LAN1
R3(config-if)#exit

R3(config)#interface s0/1/0
R3(config-if)#ip address 172.16.50.1 255.255.255.252
R3(config-if)#no shutdown
R3(config-if)#description Connection to Router2
R3(config-if)#exit

R3(config)#ip route 192.168.20.0 255.255.255.0 172.16.50.2 150
R3(config)#ip route 192.168.30.0 255.255.255.0 172.16.50.2 150
R3(config)#do sh ip int
R3(config)#do show run | begin ip route
R3(config)#do show ip route

R2 Configuration

Router>enable
Router#configure terminal
Router#config)#hostname R2

R2(config)#interface f0/0
R2(config-if)#ip address 192.168.10.1 255.255.255.0 1
R2(config-if)#no shutdown
R2(config-if)#description Connection to PC
R2(config-if)#exit

R2(config)#interface s0/1/0
R2(config-if)#ip address 172.16.50.2 255.255.255.252
R2(config-if)#no shutdown
R2(config-if)#description Connection to Router3
R2(config-if)#exit

R2(config)#interface s0/1/1
R2(config-if)#ip address 172.16.50.6 255.255.255.252
R2(config-if)#no shutdown

R2(config-if)#description Connection to Router4
R2(config-if)#exit

R2(config)#ip route 192.168.10.0 255.255.255.0 172.16.50.1 150
R2(config)#ip route 192.168.20.0 255.255.255.0 172.16.50.5 150
R2(config)#do show ip interface brief
R2(config)#do show run | begin ip route
R2(config)#do show ip route

R4 Configuration

Router>enable
Router#configure terminal
Router#config)#hostname R2
R4(config)#interface f0/0
R4(config-if)#ip address 192.168.20.1 255.255.255.0
R4(config-if)#no shutdown
R4(config-if)#description Connection to LAN2
R4(config-if)#exit

R4(config)#interface s0/1/1
R4(config-if)#ip address 172.16.50.5 255.255.255.252
R4(config-if)#no shutdown
R4(config-if)#description Connection to Router4
R4(config-if)#exit

R4(config)#ip route 192.168.10.0 255.255.255.0 172.16.50.6 150
R4(config)#ip route 192.168.20.0 255.255.255.0 172.16.50.6150
R4(config)#do show ip interface brief
R4(config)#do show run | begin ip route
R4(config)#do show ip route

Dynamic Routing

- Dynamic routing is when protocols are used to find networks and update routing tables on routers. This is whole lot easier than using static or default routing, but it will cost you in terms of router CPU processing and bandwidth on network links.
- A routing protocol defines the set of rules used by a router when it communicates routing information between neighboring routers.
- Two types of routing protocols:
  - Interior gateway protocols (IGB)
  - Exterior gateway protocols (EGP)

- IGPs are used to exchange routing information with routers in the same autonomous system (AS).
- An AS is either a single network or a collection of networks under a common administrative domain, which basically means that all routers sharing the same routing-table information are in the same AS.
- EGPs are used to communicate between ASs. An example of an EGP is Border Gateway Protocol (BGP).

Routing Protocol Basics

Administrative Distance

- The administrative distance (AD) is used to rate the trustworthiness of routing information received on a router from a neighbor router. An administrative distance is an integer from 0 to 255, where 0 is the most trusted and 255 means no traffic will be passed via this route.
- If a router receives two updates listing the same remote network, the first thing the
- router checks is the AD. If one of the advertised routes has a lower AD than the other, then the route with the lowest AD will be chosen and placed in the routing table.
- If both advertised routes to the same network have the same AD, then routing protocol metrics like hop count and/or the bandwidth of the lines will be used to find the best path to the remote network.
- The advertised route with the lowest metric will be placed in the routing table, but if both advertised routes have the same AD as well as the same metrics,
- then the routing protocol will load-balance to the remote network, meaning the protocol will send data down each link.

Default administrative distance

Ro ute Source	Default AD
Connected Interface	0
Static route	1
External BGP	20
EIGRP	90
OSPF	110
RIP	120
External EIGRP	170
Internal BGP	200
Unknown	255 (This route will never be used)

Routing Protocols

There are three class of routing protocols:

1. Distance vector. e.g. RIP
2. Link state e.g. OSPF
3. Advance distance vector, e.g. EIGRP

Configuring RIP protocols

- To configure RIP routing, just turn on the protocol with the *router rip* command and tell the RIP routing protocol the networks to advertise.
- Remember that with static routing, we always configured remote networks and never typed a route to our directly connected networks?
- IP Routing dynamic routing is carried out the complete opposite way. **You would never type a remote network under your routing protocol—only enter your directly connected networks**!

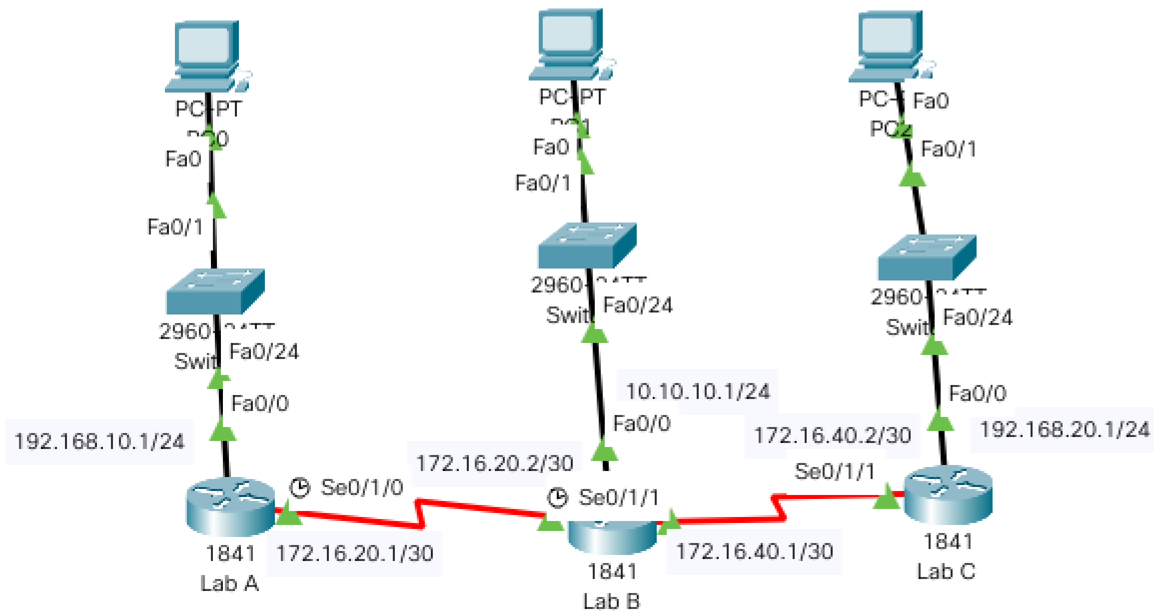
Example:
Router(config)#router rip
Router(config-router)#nework 172.16.0.0
Router(config-router)#version 2
Router(config-router)#no auto-summary

Here 172.16.0.0 is the network address directly connected to the router.
Disabling auto-summary means, we don't want our routing protocols summarizing for us because it's better to do that manually and both RIP and EIGRP auto-sumarize by default. It allows them to advertise subnets.

<u>To verify configuration of RIP protocol</u>
Router#show ip route
Router#show ip route rip
Router#show ip route database

In the output, you can see R. An R indicates that the networks were added dynamically using the RIP routing protocol. You can observe [120/1]; it represent an administrative distance and hop count.

Task: Configure RIP for the following LAN topology.



<u>Configuration of Router Lab-A</u>
Router>en

Router#config t
Enter configuration commands, one per line. End with CNTL/Z.
Router(config)#int f0/0
Router(config-if)#ip add 192.168.10.1 255.255.255.0
Router(config-if)#no shutdown

Router(config-if)#int s0/1/0
Router(config-if)#ip add 172.16.20.1 255.255.255.252

Router(config-if)#no shutdown
Router(config-if)#exit

Lab-(config)#hostname Lab-A
Lab-A(config)#router rip
Lab-A(config-router)#network 172.16.0.0
Lab-A(config-router)#network 172.16.0.0
Lab-A(config-router)#version 2
Lab-A(config-router)#no auto-summary
Lab-A(config-router)#end
Lab-A#show ip protocols
Lab-A#show ip route
Lab-A#show run

<u>Configuration on router Lab-B</u>

Router>enable
Router#configure terminal
Router(config)#hostname Lab-B
Lab-B(config)#int f0/0
Lab-B(config-if)#ip address 10.10.10.1 255.255.255.0
Lab-B(config-if)#no shutdown
Lab-B(config-if)#exit

Lab-B(config)#interface s0/1/0
Lab-B(config-if)#ip address 172.16.20.2 255.255.255.252
Lab-B(config-if)#no shutdown

Lab-B(config-if)#exit
Lab-B(config)#interface s0/1/1
Lab-B(config-if)#ip address 172.16.40.2 255.255.255.252
Lab-B(config-if)#no shutdown
Lab-B(config-if)#exit

Lab-B(config)#router rip
Lab-B(config-router)#network 172.16.0.0
Lab-B(config-router)#network 10.0.0.0
Lab-B(config-router)#version 2
Lab-B(config-router)#no auto-summary

Lab-B(config-router)#end
Lab-B#show ip route

Configuration on router Lab-C
Router>enable
Router#configure terminal
Router(config)#hostname Lab-C
Lab-C(config)#int f0/0
Lab-C(config-if)#ip address 192.168.20.1 255.255.255.0
Lab-C(config-if)#no shutdown
Lab-C(config-if)#exit

Lab-C(config)#interface s0/1/1
Lab-C(config-if)#ip address 172.16.40.2 255.255.255.252
Lab-C(config-if)#no shutdown
Lab-C(config-if)#exit

Lab-C(config)#router rip
Lab-C(config-router)#network 172.16.0.0
Lab-C(config-router)#network 192.168.20.0
Lab-C(config-router)#version 2
Lab-C(config-router)#no auto-summary
Lab-C(config-router)#end
Lab-C#show ip route

To verify the connectivity between all networks and hosts
Open command prompt terminal of any host and ping to IP addresses of all network and hosts. For example:
C:\> 192.168.20.1
C:\> 192.168.10.1
C:\> 172.16.20.1

Open Shortest Path First

- Open Shortest Path First is an open standard routing protocol that's been implemented by
- a wide variety of network vendors, including Cisco. And it's that open standard character-
- istic that's the key to OSPF's flexibility and popularity.
- It is the first link-state routing protocol.
- It uses the Dijkstra algorithm to initially construct a shortest path tree.

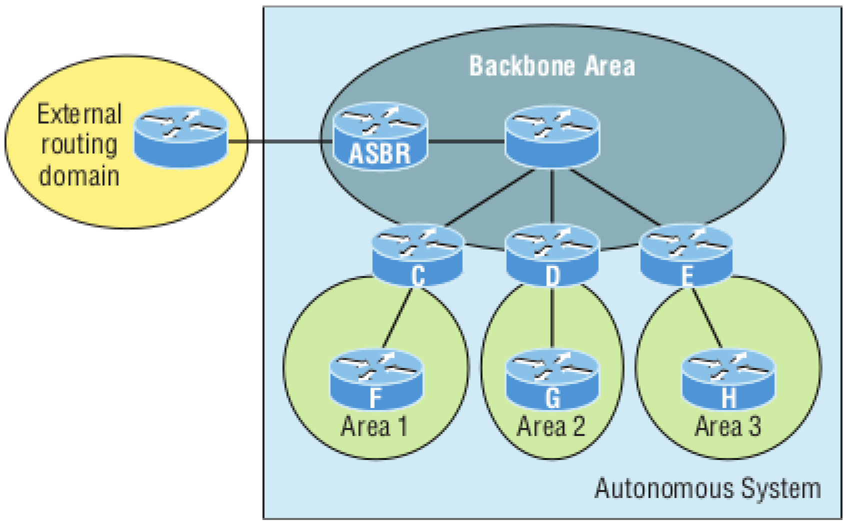


Figure: OSFP design example. An OSPF hierarchical design minimizes routing table entries and keep the impact of any topology changes contained within a specific area.

- OSPF runs great inside an autonomous system, but it can also connect multiple autonomous systems together. The router that connects these ASs is called an *autonomous system boundary router* (ASBR).

OSPF Terminology

Link: A link is a network or router interface assigned to any given network.
Router ID: The router ID (RID) is an IP addresss used to identify the router.
Neighbor: Neighbor are two or more routers that have an interface on a common network, such as as two routers connected on a point-to-point serial link.
Adjacency: An adjacency is a relationship between two OSPF routers that permits the direct exchange of route updates. Neighbor don't always form adjacency.
Designated router: A designated router (DR) is elected whenever OSPF routers are connected to the same broadcast network to minimize the number of adjacencies formed and to publicize received routing information to and from the remaining routers on the broadcast network or link.

ABR : An Area Border Router is a router that is in area 0, and one or more other areas.
ASBR: The Autonomous System Boundary Router is very special, but confusing. The ASBR connects one or more AS, and exchanges routes between them. The ASBR's purpose is to redistribute routes from another AS into its own AS.
Hello protocol: This is how routers on a network determine their neighbors and form Link State Advertisments (LSAs). Hello packets are addressed to multicast address 224.0.0.5.
Neighborship database: The neighborship database is a list of all OSPF routers for which Hello packets have been seen.
Topological database: The topological database contains information from all of the Link State Advertisement packets that have been received for an area. The router uses the information from the topology database as input into the Dijkstra algorithm that computes the shortest path to every network.
Link State Advertisement: A Link State Advertisement (LSA) is an OSPF data packet containing link-state and routing information that's shared among OSPF routers. All of the routers within the same area have the same topology table.

OSPF Operation

OSPF operation is basically divided into these three categories:

i. Neighbor and adjacency initialization
ii. LSA flooding
iii. SPF tree calculation

OSPF Metrics

OSPF uses a metric referred to as cost. A cost is associated with every outgoing interface included in an SPF tree. The cost of the entire path is the sum of the costs of the outgoing interfaces along the path. Because cost is an arbitrary value as defined in RFC 2338, Cisco had to implement its own method of calculating the cost for each OSPF-enabled interface. Cisco uses a simple equation of 10^8/bandwidth, where bandwidth is the configured bandwidth for the interface. Using this rule, a 100 Mbps Fast Ethernet interface would have a default OSPF cost of 1 and a 1,000 Mbps Ethernet interface would have a cost of 1.n This value can be overridden with the *ip ospf cost* command.

Configuring OSPF

OSPF process ID

Router>enable
Router#config terminal
Router(config)#router ospf 1
Router(config-ospf)#network *10.0.0.0* 0.255.255.255 area 0
Router(config-ospf)#end
Router#

Network Wildcard Mask OSPF area ID

Explanation:

There are two elements of OSPF configuration:

- enabling OSPF
- configuring OSPF areas

Enabling OSPF

First of all, OSPF routing process is activated as follows:

Router(config)#router ospf ?
<1-65535>

A value in the range from 1 to 65,535 identifies the OSPF process ID. It’s a unique number on this router that groups a series of OSPF configuration commands under a specific running process. Different OSPF routers don’t have to use the same process ID to communicate. It’s a urely local value that doesn’t mean a lot, but you still need to remember that it cannot start at 0; it has to start at a minimum of 1.

Configuring OSPF Areas

After identifying the OSPF process, you need to identify the interfaces that you want to activate OSPF communications on as well as the area in which each resides. This will also configure the networks you’re going to advertise to others. OSPF uses wildcards in the configuration, which are also used in the access list configurations.

OSPF routers will become neighbors only if their interfaces share a network that’s configured to belong to the same area number.

```
Router#config t
Router(config)#router ospf 1
Router(config-router)#network 10.0.0.0 0.255.255.255 area ?
        <0-4294967295> OSPF area ID as a decimal value
        A.B.C.D         OSPF area ID in IP address format
Router(config-router)#network 10.0.0.0 0.255.255.255 area 0
```

Verifying OSFP on router

```
Router# sh ip ospf
Router#sh ip ospf neighbor
Router#sh ip ospf interface
Router#sh ip ospf interface f0/0            //f0/0 is configured to OSPF
Router#sh ip ospf database
```

Task: Configure OSPF in above LAN topology.

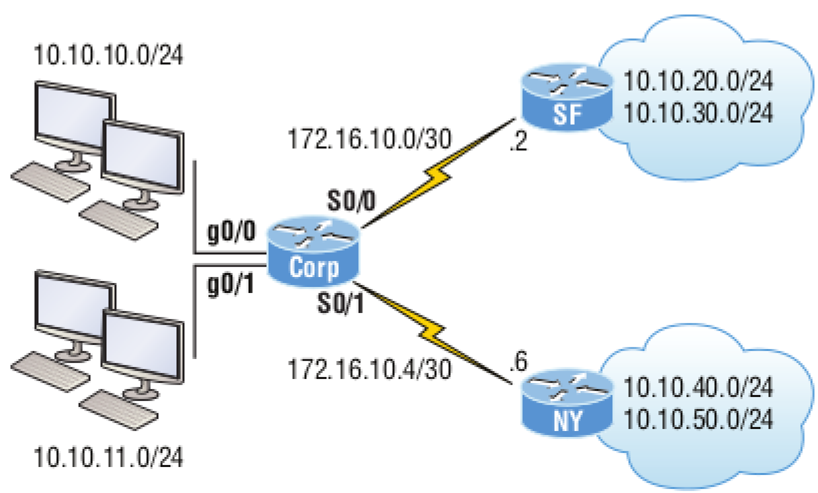
Enhanced Interior Gateway Routing Protocol (EIGRP)

- EIGRP is a classless, distance-vector protocol that uses the concept of an autonomous system to describe a set of contiguous routers that run the same routing protocol and share routing information, which also includes the subnet mask in its route updates.
- EIGRP is sometimes referred to as a hybrid routing protocol or an advanced distance-vector protocol because it has characteristics of both distance-vector and some link-state protocols. For example, EIGRP doesn't send link-state packets like OSPF does. Instead, it sends traditional distance-vector updates that include information about networks plus the cost of reaching them from the perspective of the advertising router.
- EIGRP has link-state characteristics as well—it synchronizes network topology information between neighbors at startup and then sends specific updates only when topology changes occur (bounded updates).

Features of EIGRP

- Supports for IPv4 and IPv6.
- Considered classless (same as RIPv2 and OSPF)
- Support for VLSM/CIDR
- Support for summaries and discontiguous networks
- Efficient neighbor discovery
- Communication via Reliable Transport Protocol (RTP)
- Best path selection via Diffusing Update Algorithm (DUAL)
- Reduced bandwidth usage with bounded updates
- No broadcasts

Configuring EIGRP



Corp#config t

Corp(config)#router eigrp 20
Corp(config-router)#network 10.10.11.0 0.0.0.255
Corp(config-router)#network 172.16.10.0. 0. 0. 0.3
Corp(config-router)#network 172.16.10.04 0. 0. 0.3
Corp(config-router)#no auto-summary

Verifying EIGRP
Corp#show ip route
Corp#show ip route eigrp
Corp#show ip eigrp neighbors
Corp#show ip eigrp topology
Corp#show ip eigrp traffic
Corp#show ip eigrp interfaces
Corp#show ip eigrp events
Corp#show ip interface detail S0/0
Crop#show ip route | section 10.10.11.0
Corp#show ip protocols
Corp#debug eigrp packet
Crop#debug ip eigrp events