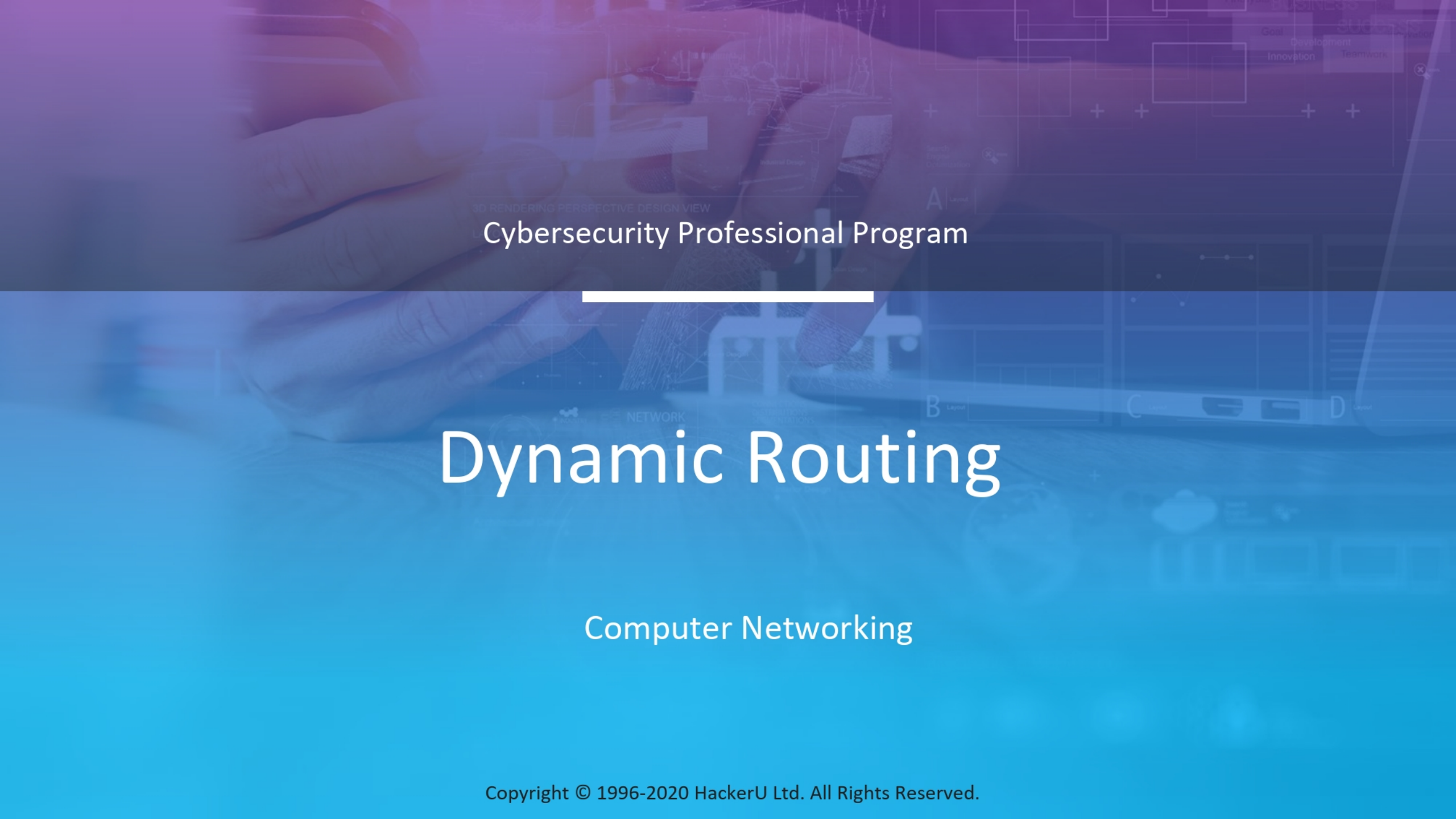


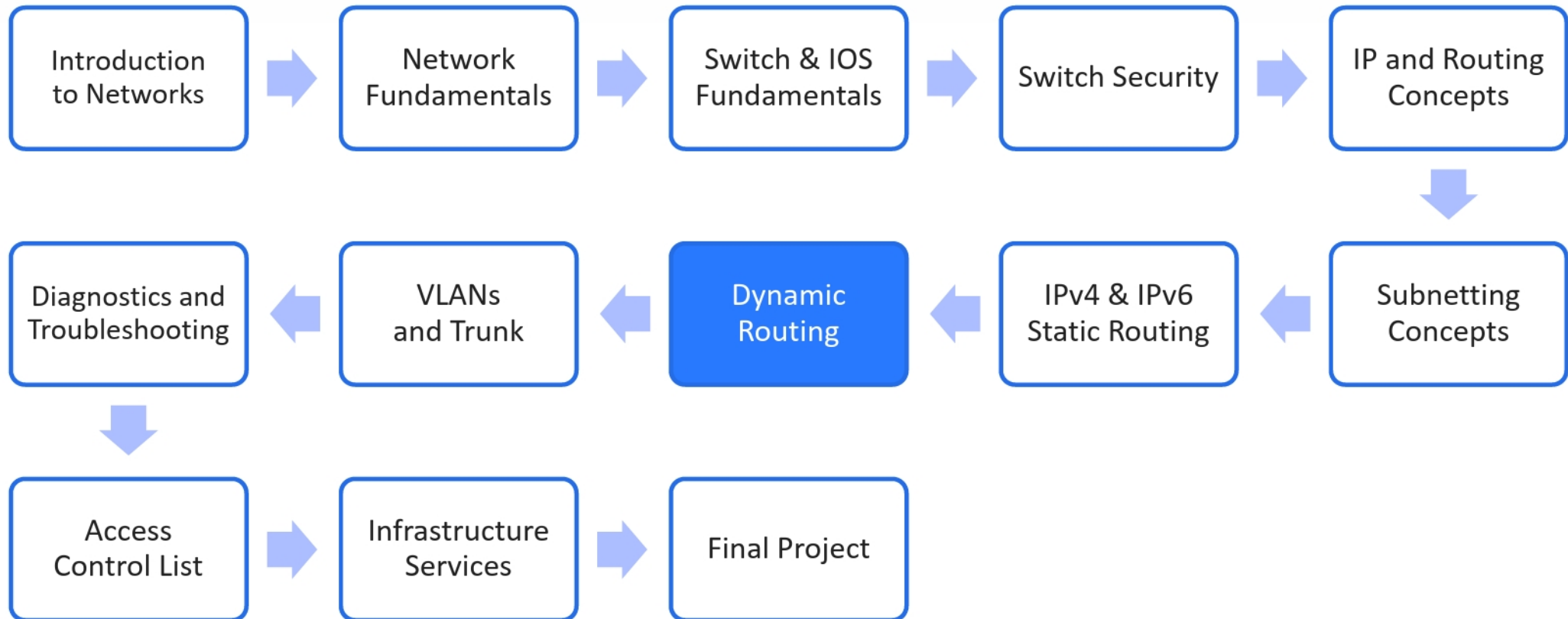


Cybersecurity Professional Program

Dynamic Routing

Computer Networking

Computer Networking Course Path



Overview

Lesson Objective

This lesson covers dynamic routing concepts and protocols, including RIPv2 and OSPFv2. It also explains processes, algorithms, and messages used to exchange routing information.



Dynamic Routing Concepts

RIPv2

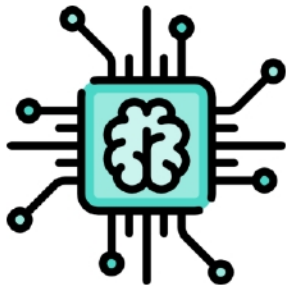
OSPFv2

Dynamic Routing

DYNAMIC ROUTING CONCEPTS

Overview

What is Dynamic Routing?



Dynamic routing protocols have been in use since the late 1980s.

The purpose of these protocols is to map networks and update routing tables with the shortest routes, in a fully automatic and independent manner.

The method is made possible by special algorithms and protocol packets.



Routing Table

The output on the right is an example of a routing table with network information learned using a dynamic routing protocol called OSPF.

The **show ip route** command output lists which local and remote networks the router “knows”.

Command Output

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

Gateway of last resort is not set

```
C 192.168.4.0/24 is directly connected, Serial2/0
C 192.168.5.0/24 is directly connected, FastEthernet0/0
O 192.168.1.0/24 [110/129] via 192.168.4.1, 00:00:52, Serial2/0
O 192.168.2.0/24 [110/128] via 192.168.4.1, 00:00:52, Serial2/0
O 192.168.3.0/24 [110/65] via 192.168.4.1, 00:00:52, Serial2/0
```



Routing Source Codes

Static



S – Indicates that the route was manually created by an administrator to reach a specific network.

EIGRP



D – Indicates that the route was learned dynamically from another router using the **EIGRP** routing protocol (which will not be covered during this course).

OSPF



O – Indicates that the route was learned dynamically from another router using the **OSPF** routing protocol.

RIP



R – Indicates that the route was learned dynamically from another router using the **RIP** routing protocol.

Key Elements

Fits Any Topology



Once the protocols are activated, the routers begin “talking” to each other, and map the network topologies themselves.



Fast and Independent



Dynamic Routing is based on software that can gather a lot of information in a short time and input it to an algorithm that computes the information to find the fastest route to each network.



Awareness



Each Dynamic Routing protocol uses Timers that detect any change in the topology, such as a connection failure. When a change is detected and involves a network failure, the protocols will search for an alternate path.



Administrative Distance (AD) Values

AD is a predefined value. The following table lists default AD values for different routing methods.

Default AD Values

Method/Protocol	AD
Directly Connected	0
Static Route	1
Internal EIGRP	90
OSPF	110
RIP	120



Metrics

What is a Metric?



A metric is a measurable value assigned by the routing protocol to different routes based on the usefulness of the route.

When there are multiple paths to a remote network in the same protocol, routing metrics are used to determine the overall “length” of a path from source to destination.

Routing protocols determine the best path based on the route with the lowest metric value.



Routing Protocol Metrics

Routing Information Protocol



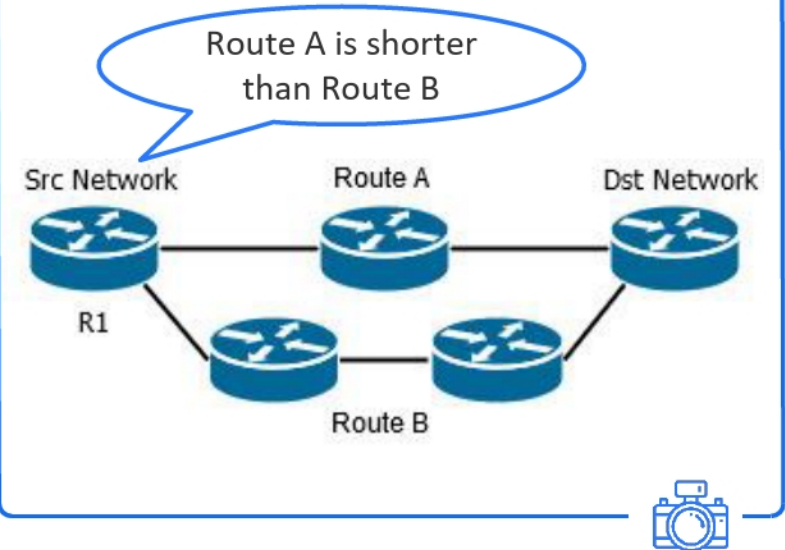
The RIP hop count metric will choose the path with the least amount of hops, where hops refer to routers.

Open Shortest Path First



The OSPF metric is based on cumulative bandwidth from source to destination. OSPF will choose the path with the highest bandwidth.

Hop Count Metric Example



EIGRP uses a metric based on minimum bandwidth, delay, load, and reliability.

Protocol Types

IGP Vs EGP

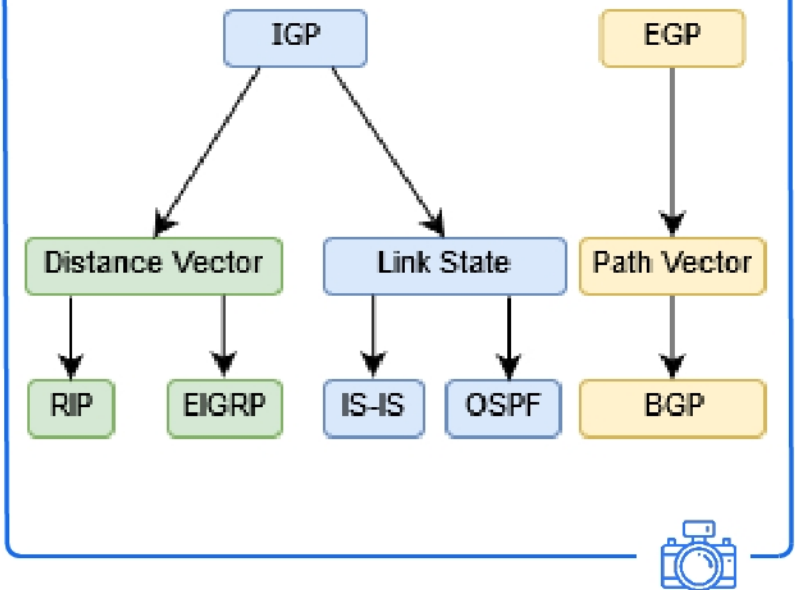
Interior Gateway Protocols are routing protocols used within an Autonomous System (AS), such as company routers.

Exterior Gateway Protocols are used to map routes between AS's, and are mainly used by ISPs.

Distance Vector Vs Link-State

The fundamental difference between distance vector and link-state routing protocols, is how the protocols discover the topology and the way they share routing information with the routers.

Protocol Classification Map



BGP is classified as a Path Vector protocol and is used to map the Internet.

Distance Vector

Distance Vector



Distance Vector is a routing algorithm that calculates the best path for a packet based on the factors of Distance and Vector.



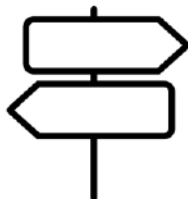
Distance



Distance – The distance between the router and the destination network, based on the metric of number of hops (routers).



Vector



Vector – The outgoing interface and the direction to the path that leads to the destination network.



Link State

Link State



Link State routing protocols include complete network topology maps.



Network Map



The map is created based on information gathered from all routers on the network.



Network Changes



Link State routing protocols do not broadcast information regularly.

Updates are only sent when a change occurs on the network.



Passive Interface

Passive Interface Feature



Passive interface is a feature used in all routing protocols. Its purpose is to disable routing updates on specific interfaces, which decreases resource usage and increases security.

The command syntax is the same in all routing protocols. It is typically placed on interfaces facing the LAN.



Passive interfaces should not be configured between routers.

Why Use Passive Interfaces?

Bandwidth



Dynamic routing updates consume bandwidth because messages are sent in broadcast or multicast, causing switches to broadcast to all ports.

Resources



Devices in the same LAN must process updates up to Layer 4 (transport layer), and only then discard the update.

Security



Packet sniffing software can be used to intercept packets that include routing updates, and redirect traffic by corrupting the routing table with false metrics.

- Dynamic Routing Concepts

Classful & Classless Routing Protocols

Classful

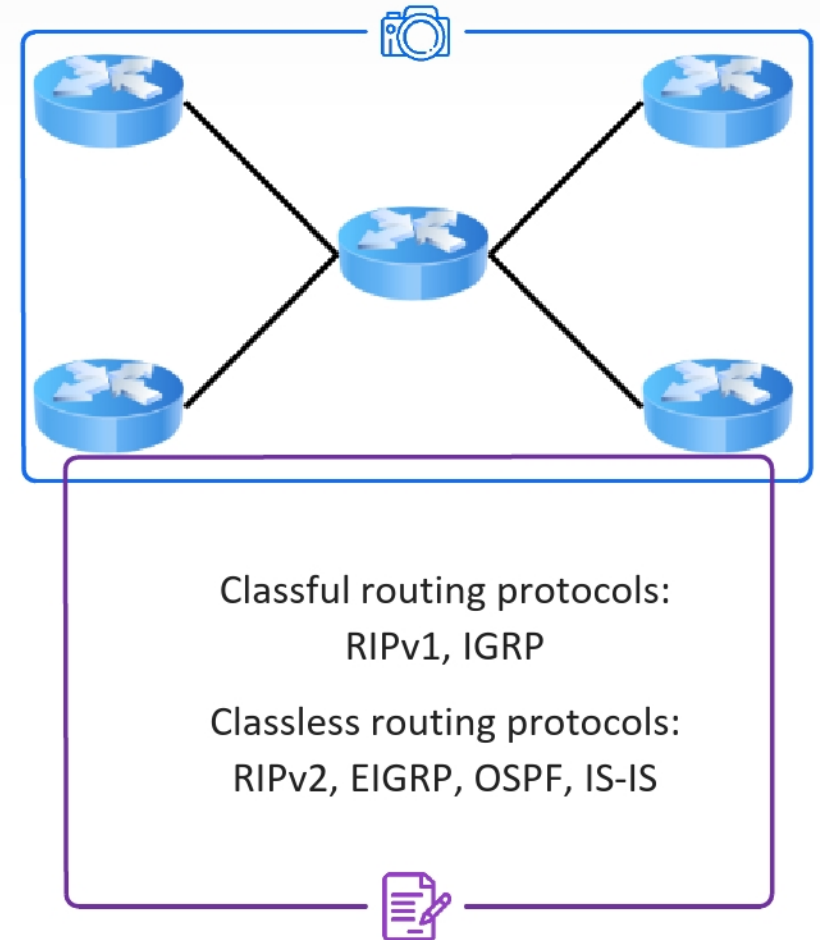


Classful routing protocols provide routing updates according to classful network addresses (A, B, C). For example, the route for 10.15.30.2/11 and 10.80.0.15/11 will be advertised as 10.0.0.0 even if it is subnetted.

Classless



Classless routing protocols provide routing updates according to VLSM addresses and does not follow only classful addresses. For example, the route for 10.80.30.2/11 will be advertised as 10.64.0.0/11



Dynamic Routing

RIPV2

RIP Overview

Routing Information Protocol



RIPv1 was released in 1988 and is one of the oldest routing protocols. It is a distance-vector protocol, and its metric method is hop count. The protocol has limitations, such as the maximum allowed hops for a route, which is 15. Due to its limitations, it is often implemented only in small networks that do not require a high level of scalability. Unlike other protocols, RIP operates in Layer 7 (OSI) and uses port 520 (UDP).



There are three versions of the protocol. RIPv2 is the most widely used, but is not the most popular, due to its inherent limitations.

RIPv2

RIP Version Comparison

RIPv1

Released in 1988

Classful routing protocol

Doesn't support VLSM and CIDR

Hop-count metric

Doesn't include subnet mask in routing updates

Routing updates are sent in broadcast (255.255.255.255)

Doesn't support authentication

Sends full routing updates



VS

RIPv2

Released in 1993

Classless routing protocol

Supports VLSM and CIDR

Hop-count metric

Includes subnet mask in routing updates

Routing updates are sent in multicast (224.0.0.9)

Supports authentication

Sends full routing updates



VS

RIPng

Released in 1997

Supports IPv6

Hop-count metric

Includes subnet mask in routing updates

Routing updates are sent in multicast (ff02::9)

Supports IPv6 inherent IPsec authentication

Sends full routing updates



RIP Parameters

Administrative Distance



RIP's default AD value is **120**.

The value can be modified, but it is not recommended to do so.



Metric



RIP determines the shortest route to a network by the number of hops (routers) to the target network. The route with the least amount of hops is added to the routing table. RIP supports routes of up to 15 hops.



RIP Timers

Update



By default, the update value is 30 seconds, and messages will be broadcast/multicast on a RIP-enabled interface.

Example: Two interconnected neighbor routers send each other updates every 30 seconds, even if there is no change in the topology.

Invalid



Invalid is also known as an expiration timer, and by default its value is 180 seconds, after which the routing entry will indicate destination is unreachable.

Example: If a router does not receive an update from its neighbor within 180 seconds, it will set the route's hop count to 16 (destination is unreachable).

Flush



If a route is invalid after 180 seconds, it will remain in the routing table for an additional 60 seconds before it is removed, and inform its neighbors of its status.

Total: $180+60=240$

Hold-down

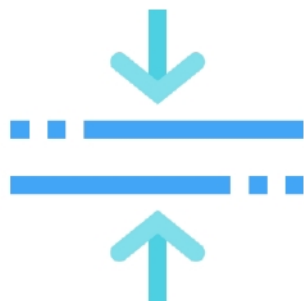


The default value is 180 seconds.

During this time, the router will not accept new updates for the route.

Auto-Summary

Auto-Summarization Feature



Auto Summary is a feature that allows automatic summarization of routes to their classful networks. This allows multiple networks to be represented with a single summary address.

By default, RIP and EIGRP summarize subnets exceeding the classful boundaries to a major classful network address in the routing updates.



This feature is often disabled because most address schemes in networks today do not allow address summaries without compromising communication.

RIPv2

Network Topology Example

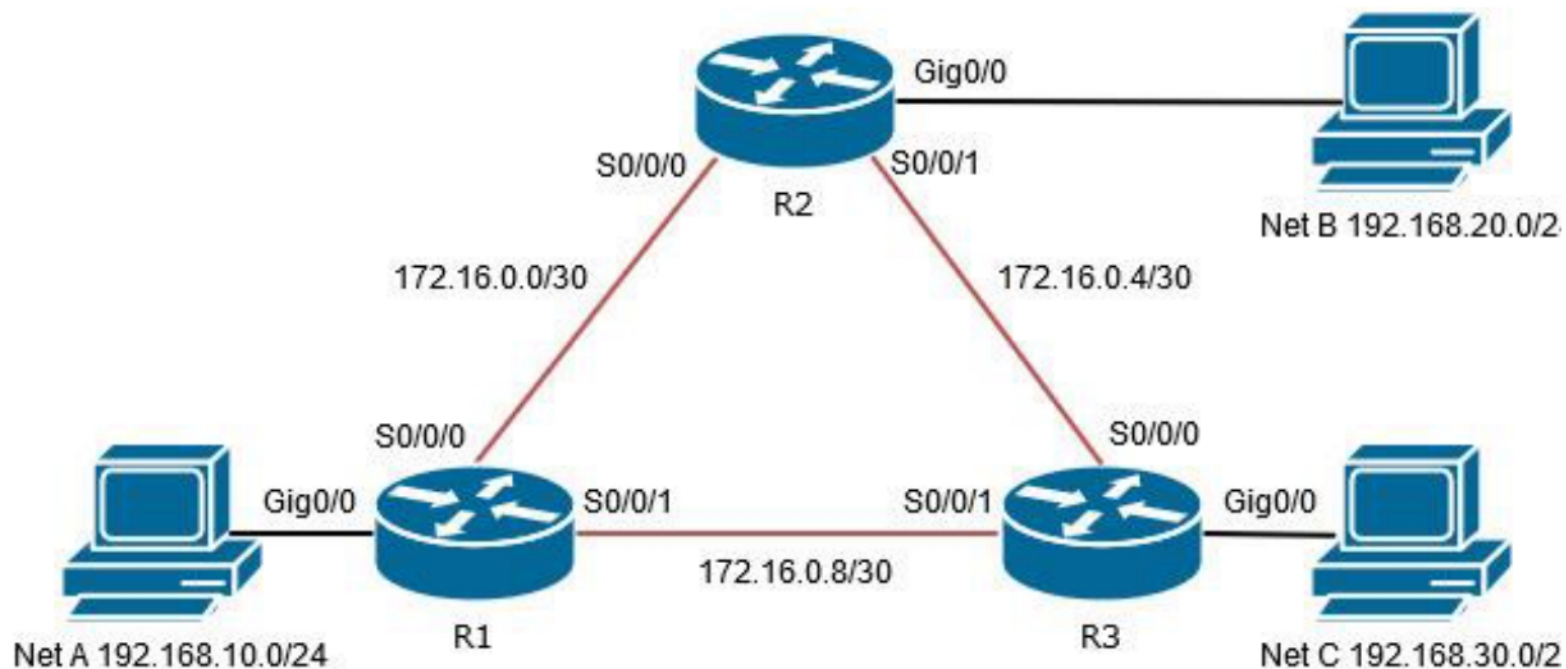
Networks A, B, and C cannot reach each other because their routers do not 'know' each other yet.

Once RIP is enabled on all routers, they will start to share routing information.

Next, each router will add remote networks to its table. R1 will add Nets B and C, for example.

This process is called **convergence**.
Every router can reach any network.

Network Illustration



RIPv2 Configuration Example

router rip enables RIP and enters RIP configuration mode.

version sets the RIP version.

network advertises the network and enables RIP updates on the network interface.

no-summary disables the auto-summary feature.
passive-interface disables RIP updates on the interface.

Settings on R1 and R2

```
R1(config)#router rip
R1(config-router)#version 2
R2(config-router)#no auto-summary
R1(config-router)#network 192.168.10.0
R1(config-router)#network 172.16.0.0
R1(config-router)#network 172.16.0.8
R1(config-router)#passive-interface gigabitEthernet 0/0
```

```
R2(config)#router rip
R2(config-router)#version 2
R2(config-router)#no auto-summary
R2(config-router)#network 192.168.20.0
R2(config-router)#network 172.16.0.0
R2(config-router)#network 172.16.0.4
R2(config-router)#passive-interface gigabitEthernet 0/0
```



Verify RIPv2 on R1

The example on the right shows R1's routing table after RIP finished updating it. **R** represents the route learned by the RIP protocol.

An important feature is that if the router finds two equal paths to the network, both routes are added to the table, and load balancing is applied. For example, **172.16.0.4/30**

R1 Routing Table

```
R1#show ip route
```

```
      172.16.0.0/16 is variably subnetted, 5 subnets, 2 masks
C       172.16.0.0/30 is directly connected, Serial0/0/0
L       172.16.0.1/32 is directly connected, Serial0/0/0
R       172.16.0.4/30 [120/1] via 172.16.0.2, 00:00:05, Serial0/0/0
                        [120/1] via 172.16.0.10, 00:00:16, Serial0/0/1
C       172.16.0.8/30 is directly connected, Serial0/0/1
L       172.16.0.9/32 is directly connected, Serial0/0/1
      192.168.10.0/24 is variably subnetted, 2 subnets, 2 masks
C       192.168.10.0/24 is directly connected, GigabitEthernet0/0
L       192.168.10.254/32 is directly connected, GigabitEthernet0/0
R       192.168.20.0/24 [120/1] via 172.16.0.2, 00:00:05, Serial0/0/0
R       192.168.30.0/24 [120/1] via 172.16.0.10, 00:00:16, Serial0/0/1
```



R2 and R3 Verification

The **rip** flag shows only RIP entries in the router table.

Another method is to check the running-config file to view the current configuration.

R2 & R3 Routing Tables

```
R2#show ip route rip
```

```
    172.16.0.0/16 is variably subnetted, 5 subnets, 2 masks
R       172.16.0.8/30 [120/1] via 172.16.0.1, 00:00:24, Serial0/0/0
                                [120/1] via 172.16.0.6, 00:00:08, Serial0/0/1
R       192.168.10.0/24 [120/1] via 172.16.0.1, 00:00:24, Serial0/0/0
    192.168.20.0/24 is variably subnetted, 2 subnets, 2 masks
R       192.168.30.0/24 [120/1] via 172.16.0.6, 00:00:08, Serial0/0/1
```

```
R3#show ip route rip
```

```
    172.16.0.0/16 is variably subnetted, 5 subnets, 2 masks
R       172.16.0.0/30 [120/1] via 172.16.0.5, 00:00:09, Serial0/0/0
                                [120/1] via 172.16.0.9, 00:00:28, Serial0/0/1
R       192.168.10.0/24 [120/1] via 172.16.0.9, 00:00:28, Serial0/0/1
R       192.168.20.0/24 [120/1] via 172.16.0.5, 00:00:09, Serial0/0/0
```



Show IP Protocols

show ip protocols displays the current protocol settings. This is valid for every dynamic routing configuration, such as OSPF.

The output includes:

- Timer information
- Advertised networks
- Passive interfaces
- More

Output on R1

```
R1#show ip protocols
Routing Protocol is "rip"
Sending updates every 30 seconds, next due in 10 seconds
Invalid after 180 seconds, hold down 180, flushed after 240
Redistributing: rip
Default version control: send version 2, receive 2

  Interface          Send  Recv  Triggered RIP  Key-chain
  Serial0/0/0         2     2
  Serial0/0/1         2     2
Automatic network summarization is not in effect
Maximum path: 4
Routing for Networks:
  172.16.0.0
  192.168.10.0
Passive Interface(s):
  GigabitEthernet0/0
Routing Information Sources:
  Gateway            Distance            Last Update
Distance: (default is 120)
```



RIPv2

Routing Table Entry

Command

R	192.168.20.0/24	[120/1]	via 172.16.0.5,	00:00:09,	Serial0/0/0
1	2	3	4	5	6



1. Route source.
2. The destination network address and prefix.
3. The AD and metric of the route.
4. Next-hop address through which the packet passes to the target network.
5. The route age (timestamp).
6. The local outgoing interface that points to the target network.

Show IP Route Output

```
R1#show ip route
R 192.168.20.0/24 [120/1] via
172.16.0.5, 00:00:09, Serial0/0/0
```



The same command is used for both RIP and OSPF.

Gateway of Last Resort

Static Default Route



The static default route redirects packets with unknown destinations to the Gateway of Last Resort, which is a router that communicates in a specific direction (typically to the ISP (Internet)).



Propagating Default Routes



Each routing protocol shares its default routes with all routers on the network, through protocol updates.



Code Example

```
R1(config)#ip route 0.0.0.0  
0.0.0.0 Gig 0/1
```

```
R1(config)#router rip  
R1(config-router)#default-information  
originate
```

```
R2(config)#do show ip route  
R* 0.0.0.0/0 [120/1] via  
192.168.12.1, 00:00:26, Gig 0/1
```



Lab NET-08-L1

Configuring and Verifying RIPv2
30–60 Min.



Mission

The objective of this lab is to implement and verify dynamic routing using RIP. The RIP protocol is straightforward, and can help understand basic network routing. RIP is no longer commonly in use today.

Steps

- Configure RIPv2.
- Propagate a default route.

Environment & Tools

- OS: All platforms
- Tools: Cisco Packet Tracer 7.2.2

Related Files

- Lab document
- NET-08-L1.pka

Dynamic Routing

OSPFV2

OSPFv2

OSPF Overview

Open Shortest Path First



OSPF is a Link State routing protocol introduced in 1989, with more advanced features, making it a strong and scalable solution for any size network. OSPF was designed as an alternative to RIP.

OSPFv2 was released in 1991 and is still in use today.

OSPFv3 was developed for IPv6 in 1997.



Topology Changes and Timers

Monitor the Network



OSPFv2 keeps track of changes in the topology, such as when a new network is added, or a link fails.



Hello



Hello Intervals – “Hello” packets are sent every 10 seconds to all OSPF-enabled routers.



Dead



Dead Intervals – When a router does not receive a “hello” packet from its neighbor within 40 seconds, it will consider that neighbor “dead”, and will start looking for alternative routes.



OSPFv2

OSPF Packets

LSA



Routers use **Link State Advertisement** to advertise the routing topology to all other local routers in the same OSPFv2 area.

LSAs are sent in multicast.

LSDB



Link State Database stores received LSA packets, after the routers enable OSPFv2 to use the SPF algorithm to calculate the routes.

DBD



When an adjacency is initialized, OSPFv2 exchanges **Database Description** packets to describe the content of the topological database.

LSR



If a router notices that parts of its topological database are outdated, it will send a **Link State Request** to a neighbor for more updated versions of those components.

LSRs are sent in multicast.

LSU



Link State Update messages are responses to LSR messages.

LSUs are sent in unicast.

SPF Algorithm and Tree

Dijkstra



By calculating all routes to each network in the topology using the **Dijkstra Algorithm**, OSPFv2 creates a map of the network called an **SPF Tree**.

The SPF Tree is stored in a database on the router called a Link State Database (**LSDB**).



OSPF Metric

Best Route Determination



OSPF bases its metric calculation on the bandwidth of the links along the path to the destination.



Cost



All bandwidth information recorded for the route is calculated using the OSPF formula (all considerations are summed), resulting in the cost value.



Cost Calculation

Reference Speed (Mbps):

1000

=

Link Cost:

10

Interface Speed (Mbps):

100



The default reference speed is 100 Mbps, and can be adjusted using the **auto-cost** command.

Wildcard Masks

Mask Inversion



Wildcard masks are used in some routing protocols, such as OSPF, as inverted subnet masks.

For example, the subnet 255.255.255.0 inverts to a wildcard mask of 0.0.0.255.



Router ID

Router ID



When OSPFv2 is enabled on an interface, the router must determine if there is another OSPFv2 neighbor on the link. Router IDs are set **manually** and used to uniquely identify each router.



First Fallback



If no router ID is configured, the highest IP address of any router **Loopback Interface** is selected as the router ID.



Second Fallback



If no Loopback Interface is configured, the highest IP address among its **active interfaces** is selected as the OSPFv2 router ID.



Router ID Configuration

```
R1(config)#router ospf 1
R1(config-router)#router-id 1.1.1.1

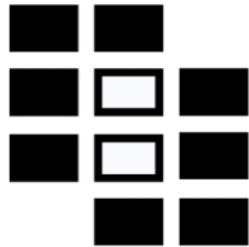
R2(config)#router ospf 1
R2(config-router)#router-id 2.2.2.2

R3(config)#router ospf 1
R3(config-router)#router-id 3.3.3.3
```



OSPFv2 Areas

What is an Area?



OSPF uses a concept called Areas. A single AS or full topology can be divided into smaller areas.

Dividing the topology into areas reduces router resource consumption and protocol response time.



OSPFv2

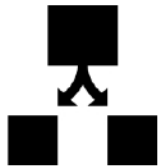
OSPFv2 Areas

Single-Area OSPF



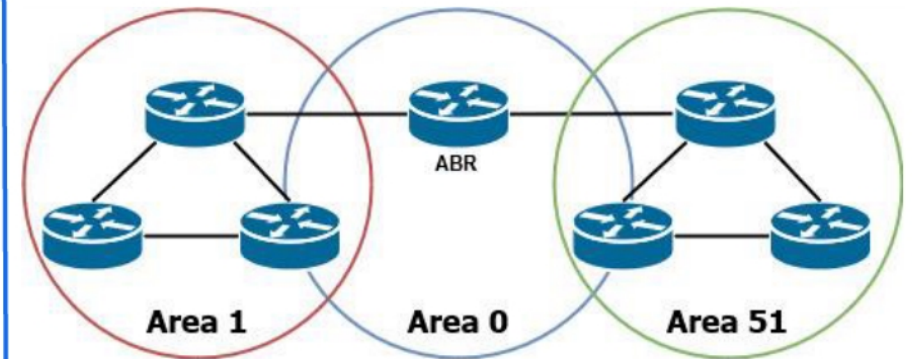
For small to medium size networks that use a single area, the default OSPFv2 is **Area 0**. The maximum recommended area is 50 routers.

Multi-Area OSPF



In larger networks that require more areas, **Area 0 will be the backbone area**, and all routers outside that area will be assigned other unique numbers (1, 2, 3, etc.).

Area Illustration



Routing between areas is done by an ABR (Area Border Router).

Area Advantages and Disadvantages

Advantages

Smaller database (LSDB) for each area, saves memory.

Smaller routing table for each area, saves resources.

Less traffic on the network due to less exchange of routing information among routers.

Reduced algorithm calculation, only within areas.

In smaller areas, updates regarding changes in the topology are distributed faster.



Disadvantages

CPU utilization is high due to the amount of SPF calculations.

OSPFv2 requires all areas to be connected to the backbone.



OSPFv2

Network Topology Example

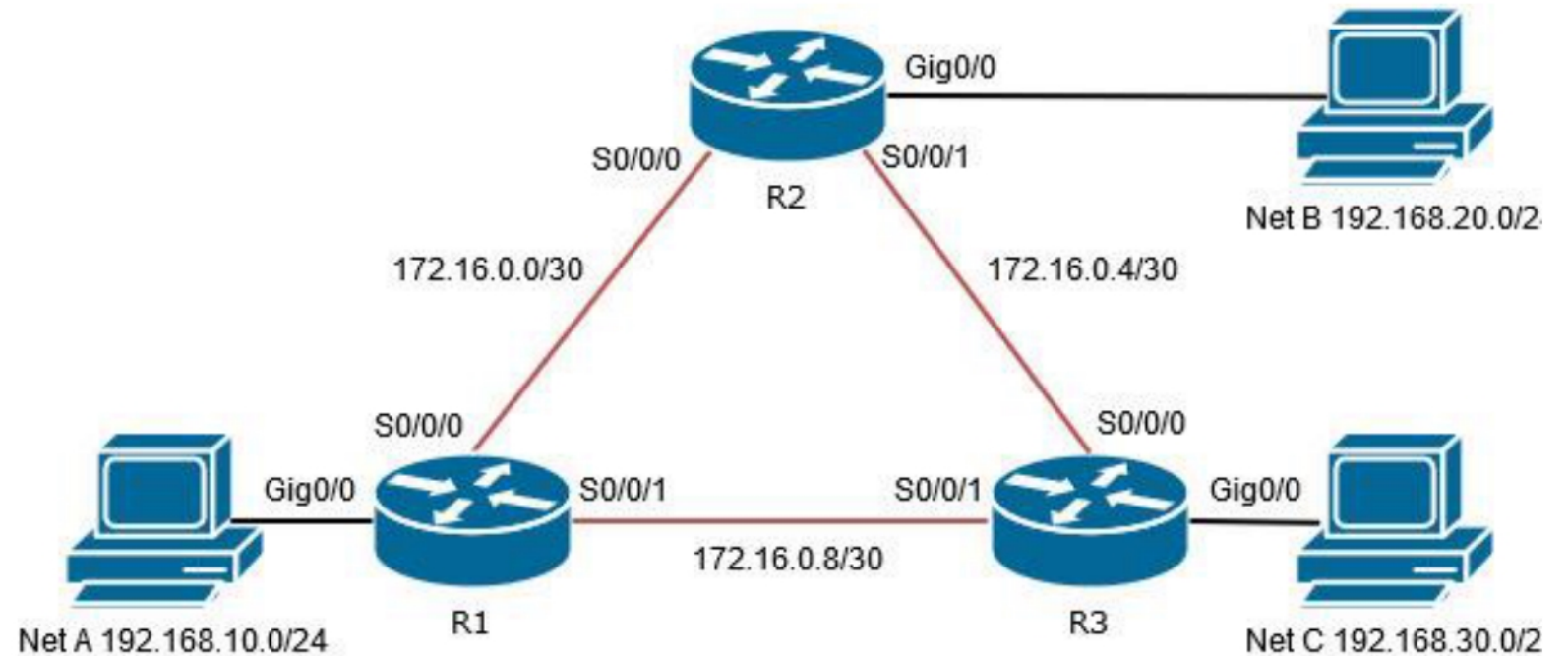
Networks A, B, and C cannot reach each other, because the routers do not 'know' each other yet.

Once OSPF is enabled on all routers, they will start to share routing information.

Next, each router adds remote networks to its table. For example, R1 will add Nets B and C.

This process is called **convergence**.
Any router can reach any network.

Network Illustration



OSPFv2 Configuration Example

router ospf enables OSPF and enters OSPF configuration mode.
router-id sets the router OSPF identifier.

network advertises the network and enables OSPF updates on the network interface.
area sets the interface area ID.
auto-cost sets the reference bandwidth calculation

passive-interface disables OSPF updates on the interface.

A log message indicates a link to another OSPF-enabled router.

Settings on R1

```
R1(config)#router ospf 1
R1(config-router)#router-id 1.1.1.1
R1(config-router)#network 192.168.10.0 0.0.0.255 area 0
R1(config-router)#network 172.16.0.0 0.0.0.3 area 0
R1(config-router)#network 172.16.0.8 0.0.0.3 area 0
R1(config-router)#auto-cost reference-bandwidth 1000
R1(config-router)#passive-interface gigabitethernet 0/0
R1(config-router)#
00:29:39: %OSPF-5-ADJCHG: Process 1, Nbr 2.2.2.2 on Serial0/0/0 from
LOADING to FULL, Loading Done

00:29:59: %OSPF-5-ADJCHG: Process 1, Nbr 3.3.3.3 on Serial0/0/1 from
LOADING to FULL, Loading Done

Please ensure reference bandwidth is consistent across all routers
```



Verify OSPF on R1

The example on the right shows R1's routing table after OSPF finished updating it.

○ represents the route learned by the OSPF protocol.

An important feature of OSPF routing is that if the router finds two equal paths to the network, both routes will be added to the table, and load balancing will be applied.

For example, **172.16.0.4/30**

R1 Routing table

```
R1#show ip route
```

```

      172.16.0.0/16 is variably subnetted, 5 subnets, 2 masks
C       172.16.0.0/30 is directly connected, Serial0/0/0
L       172.16.0.1/32 is directly connected, Serial0/0/0
O       172.16.0.4/30 [110/128] via 172.16.0.2, 00:14:35, Serial0/0/0
                        [110/128] via 172.16.0.10, 00:14:35, Serial0/0/1
C       172.16.0.8/30 is directly connected, Serial0/0/1
L       172.16.0.9/32 is directly connected, Serial0/0/1
      192.168.10.0/24 is variably subnetted, 2 subnets, 2 masks
C       192.168.10.0/24 is directly connected, GigabitEthernet0/0
L       192.168.10.254/32 is directly connected, GigabitEthernet0/0
O       192.168.20.0/24 [110/65] via 172.16.0.2, 00:14:55, Serial0/0/0
O       192.168.30.0/24 [110/65] via 172.16.0.10, 00:14:35, Serial0/0/1
```



Show IP Protocols

show ip protocols displays the current protocol settings.

The output includes:

- Router ID
- Area and process ID
- Advertised networks
- Passive interfaces
- More

show ip ospf interface displays timer information.

show ip ospf neighbor displays adjacent OSPF-enabled routers.

Output on R1

```
R1#show ip protocols
Routing Protocol is "ospf 1"
  Outgoing update filter list for all interfaces is not set
  Incoming update filter list for all interfaces is not set
  Router ID 1.1.1.1
  Number of areas in this router is 1. 1 normal 0 stub 0 nssa
  Maximum path: 4
  Routing for Networks:
    192.168.10.0 0.0.0.255 area 0
    172.16.0.0 0.0.0.3 area 0
    172.16.0.8 0.0.0.3 area 0
  Passive Interface(s):
    GigabitEthernet0/0
  Routing Information Sources:
    Gateway         Distance      Last Update
    1.1.1.1          110          00:21:40
    2.2.2.2          110          00:21:43
    3.3.3.3          110          00:21:40
  Distance: (default is 110)
```

Lab NET-08-L2

Configuring and Verifying OSPFv2
30–60 Min.



Mission

Configuring routers to use OSPF with best practices in mind.

Steps

- Configure OSPF.
- Propagate a default route.

Environment & Tools

- OS: All platforms
- Tools: Cisco Packet Tracer 7.2.2 or later

Related Files

- Lab document
- NET-08-L2.pka

An overhead photograph of three individuals working together at a rustic wooden table. The scene is captured from a high angle, showing the backs and sides of the people. On the table, there are two open laptops, a smartphone, a disposable coffee cup, and a document with blue and orange highlights. The image has a blue color overlay, and the word 'QUESTIONS?' is centered in white text.

QUESTIONS?



THANK YOU
