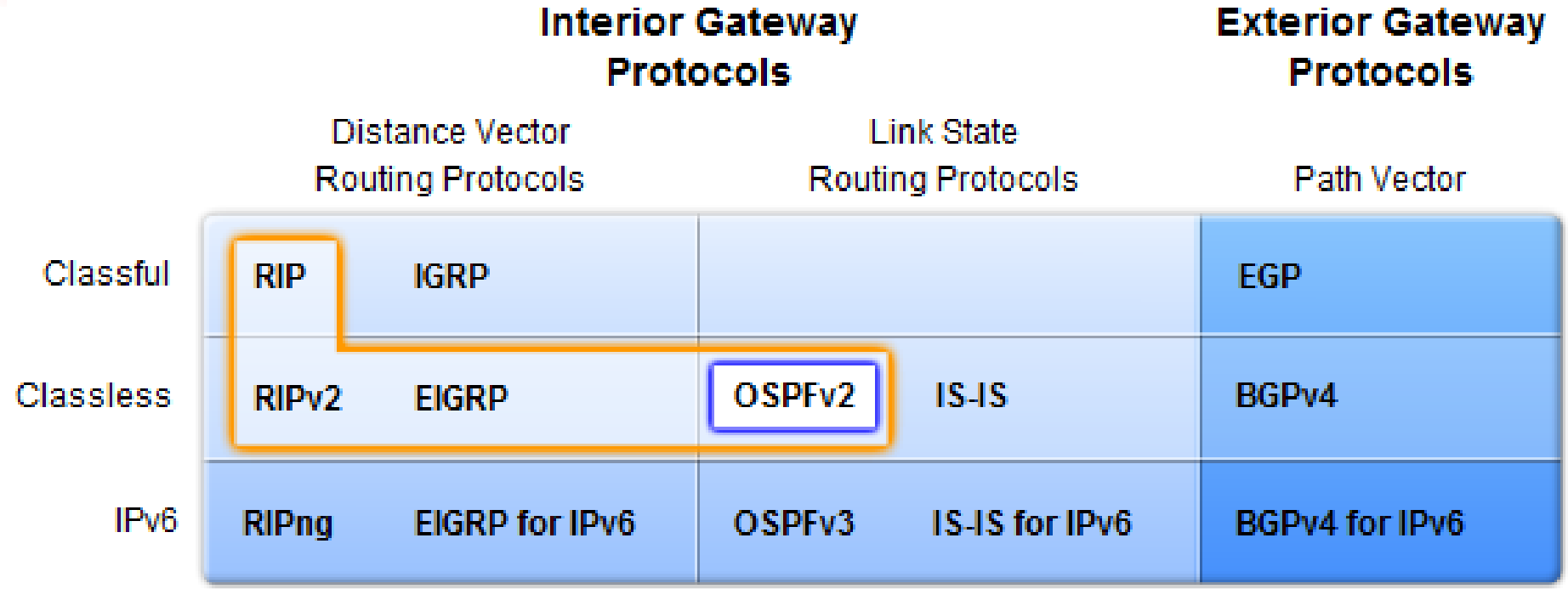
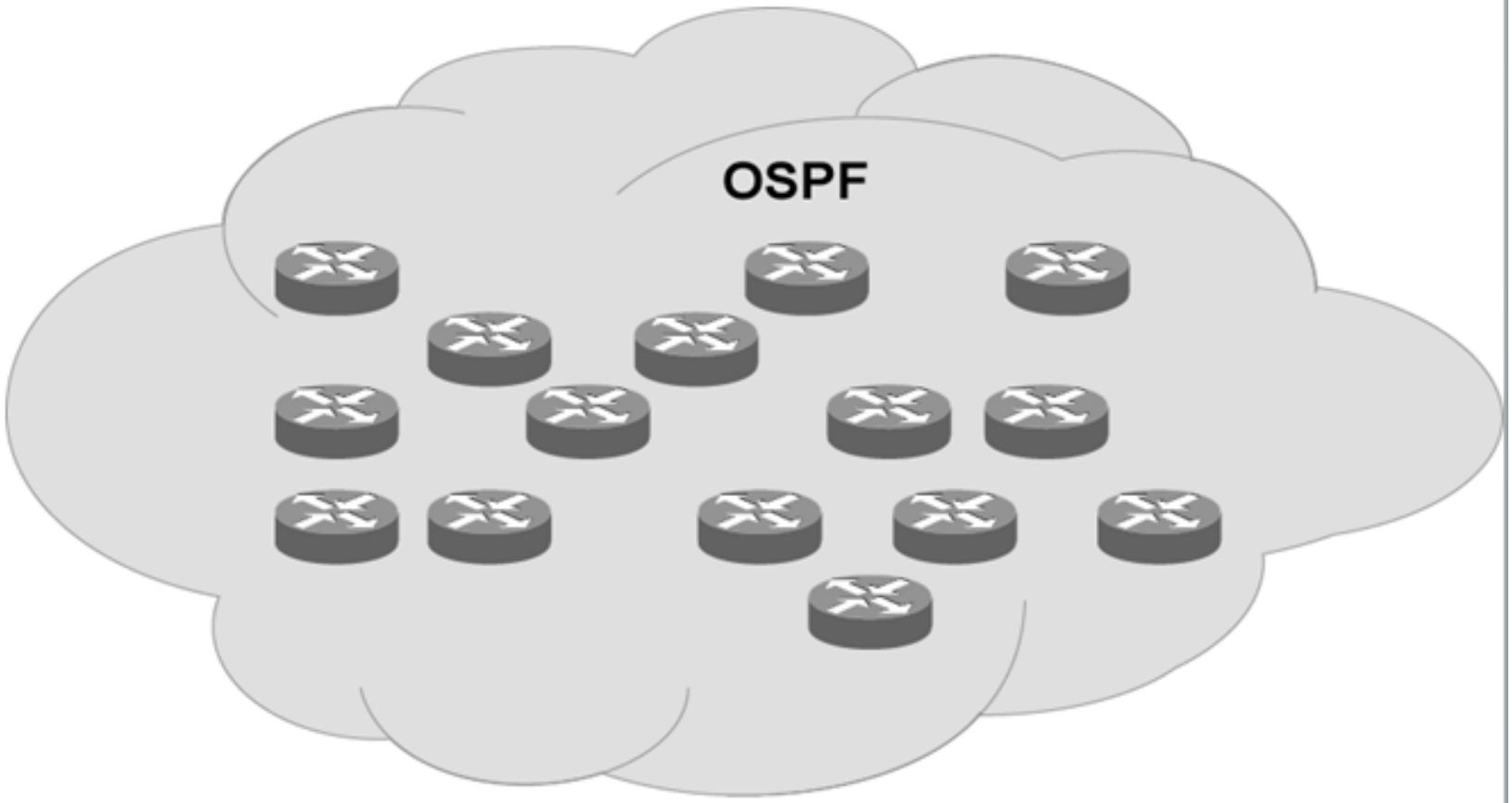
OSPF v2



Introducing OSPF



- Open standard
- Shortest path first (SPF) algorithm
- Link-state routing protocol (vs. distance vector)
- Can be used to route between AS's

Open Shortest Path First (OSPF) Basics

- open standard routing protocol
- works by using the Dijkstra algorithm to initially construct a shortest path tree and follows that by populating the routing table with the resulting best paths
- quick convergence
- supports multiple, equal-cost routes to the same destination
- supports both IPv4 and IPv6 routed protocols

Link State Vs. Distance Vector

Link State:

- Provides common view of entire topology
- Calculates shortest path
- Utilizes event-triggered updates
- Can be used to route between AS's

Distance Vector:

- Exchanges routing tables with neighbors
- Utilizes frequent periodic updates

OSPF's best features

- Allows for the creation of areas and autonomous systems
- Minimizes routing update traffic
- Is highly flexible, versatile, and scalable
- Supports VLSM/CIDR
- Offers an unlimited hop count
- Is open standard and supports multi-vendor deployment

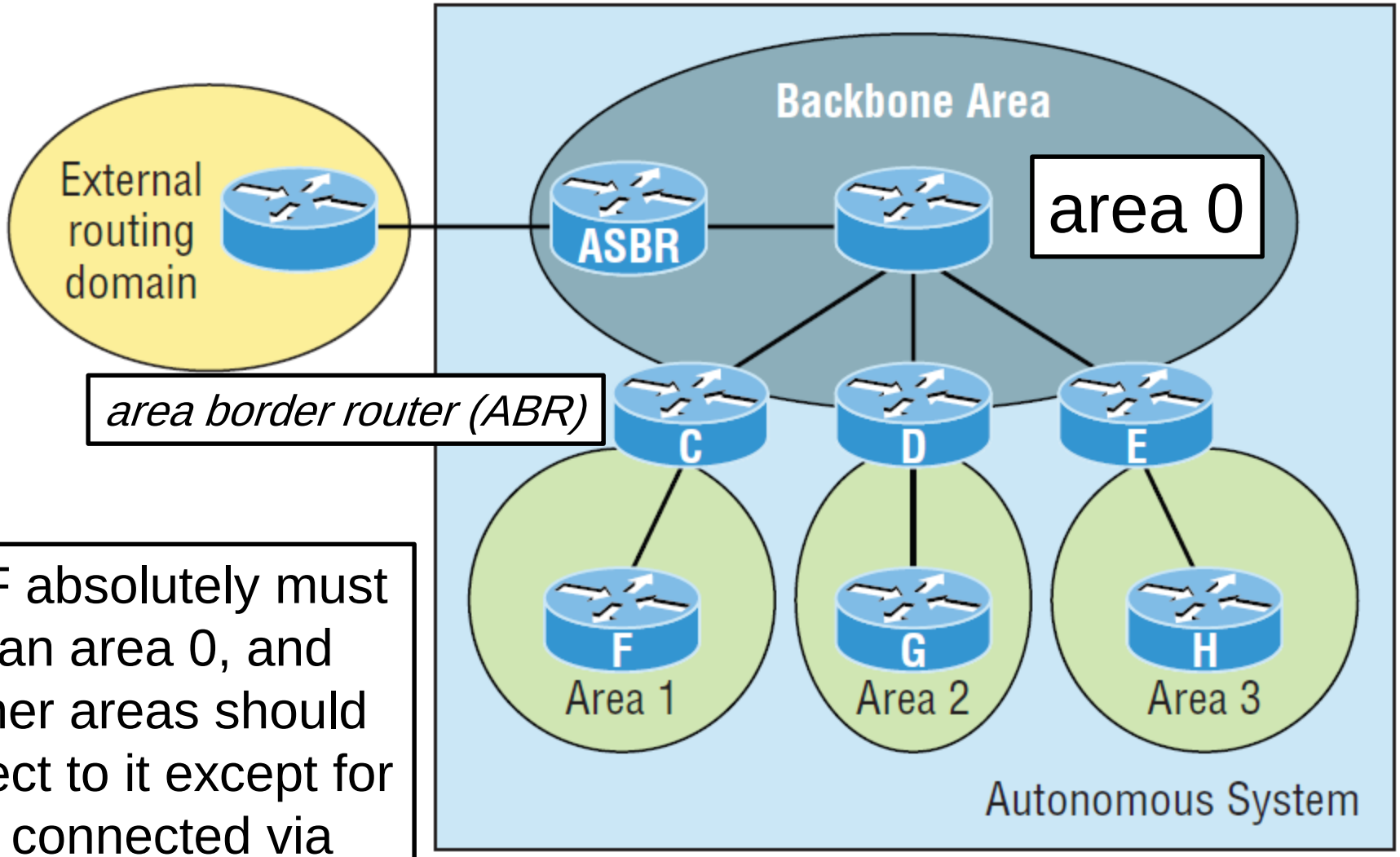
Characteristic	OSPF	RIPv2	RIPv1
Type of protocol	Link state	Distance vector	Distance vector
Classless support	Yes	Yes	No
VLSM support	Yes	Yes	No
Auto-summarization	No	Yes	Yes
Manual summarization	Yes	Yes	No
Noncontiguous support	Yes	Yes	No
Route propagation	Multicast on change	Periodic multicast	Periodic broadcast
Path metric	Bandwidth	Hops	Hops
Hop count limit	None	15	15

Characteristic	OSPF	RIPv2	RIPv1
Convergence	Fast	Slow	Slow
Peer authentication	Yes	Yes	No
Hierarchical network requirement	Yes (using areas)	No (flat only)	No (flat only)
Updates	Event triggered	Periodic	Periodic
Route computation	Dijkstra	Bellman-Ford	Bellman-Ford

OSPF basics

- Its design is intended to be hierarchical in use
  - subdivide the larger internetwork into smaller internetworks called areas
- Reasons:
  - To decrease routing overhead
  - To speed up convergence
  - To confine network instability to single areas of the network

OSPF design example



OSPF absolutely must have an area 0, and all other areas should connect to it except for those connected via virtual links

OSPF basics

- 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.
  - When an interface is added to the OSPF process, it's considered to be a link.
  - This link, or interface, will have up or down state information associated with it as well as one or more IP addresses.

OSPF Terminology

- **Router ID**
  - The *router ID (RID)* is an IP address used to identify the router.
  - Cisco chooses the router ID by using the highest IP address of all configured loopback interfaces.
  - If no loopback interfaces are configured with addresses, OSPF will choose the highest IP address out of all active physical interfaces.
  - To OSPF, this is basically the "name" of each router.

OSPF Terminology

- **Neighbor**
  - *Neighbors* are two or more routers that have an interface on a common network, such as two routers connected on a point-to-point serial link.
  - OSPF neighbors must have a number of common configuration options to be able to successfully establish a neighbor relationship, and all of these options must be configured exactly the same way:
    - Area ID
    - Stub area flag
    - Authentication password (if using one)
    - Hello and Dead intervals

OSPF Terminology

- **Adjacency**
  - An *adjacency* is a relationship between two OSPF routers that permits the direct exchange of route updates.
  - OSPF will directly share routes only with neighbors that have also established adjacencies.
  - And not all neighbors will become adjacent—this depends upon both the type of network and the configuration of the routers.

OSPF Terminology

- **Adjacency**
  - In multi-access networks, routers form adjacencies with designated and backup designated routers.
  - In point-to-point and point-to-multipoint networks, routers form adjacencies with the router on the opposite side of the connection.

OSPF Terminology

- **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.
  - Elections are won based upon a router's priority level, with the one having the highest priority becoming the winner.

OSPF Terminology

- **Designated router**
  - If there's a tie, the router ID will be used to break it.
  - All routers on the shared network will establish adjacencies with the DR and the BDR, which ensures that all routers' topology tables are synchronized.

OSPF Terminology

- **Backup designated router**
  - A *backup designated router (BDR)* is a hot standby for the DR on broadcast, or multi-access, links.
  - The BDR receives all routing updates from OSPF adjacent routers but does not disperse LSA updates.
  - LSA packets are used to update and maintain the topological database.

OSPF Terminology

- **Hello protocol**
  - The OSPF Hello protocol provides dynamic neighbor discovery and maintains neighbor relationships.
  - Hello packets and Link State Advertisements (LSAs) build and maintain the topological database.
  - Hello packets are addressed to multicast address 224.0.0.5.

OSPF message encapsulation

Data Link Frame (Ethernet Fields shown here)
MAC Source Address = Address of sending interface
MAC Destination Address = Multicast: 01-00-5E-00-00-05 or 01-00-5E-00-00-06

IP Packet
IP Source Address = Address of sending interface
IP Destination Address = Multicast: 224.0.0.5 or 224.0.0.6
Protocol field = 89 for OSPF

OSPF Packet Header
Type Code for OSPF Packet Type
Router ID and Area ID

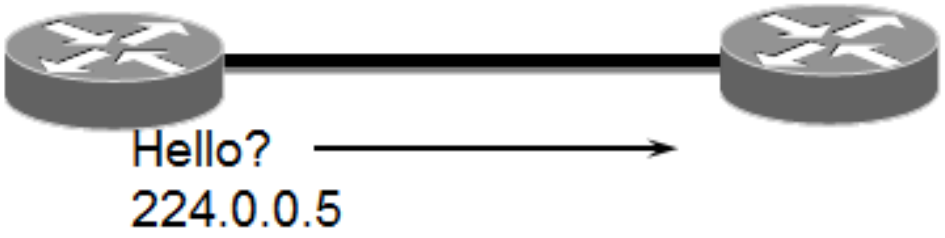
OSPF Packet Types
0x01 Hello
0x02 Database Description (DD)
0x03 Link State Request
0x04 Link State Update
0x05 Link State Acknowledgment

OSPF packet types

Type	Packet Name	Description
1	Hello	Discovers neighbors and builds adjacencies between them
2	Database Description (DBD)	Checks for database synchronization between routers
3	Link-State Request (LSR)	Requests specific link-state records from router to router
4	Link-State Update (LSU)	Sends specifically requested link-state records
5	Link-State Acknowledgement (LSAck)	Acknowledges the other packet types

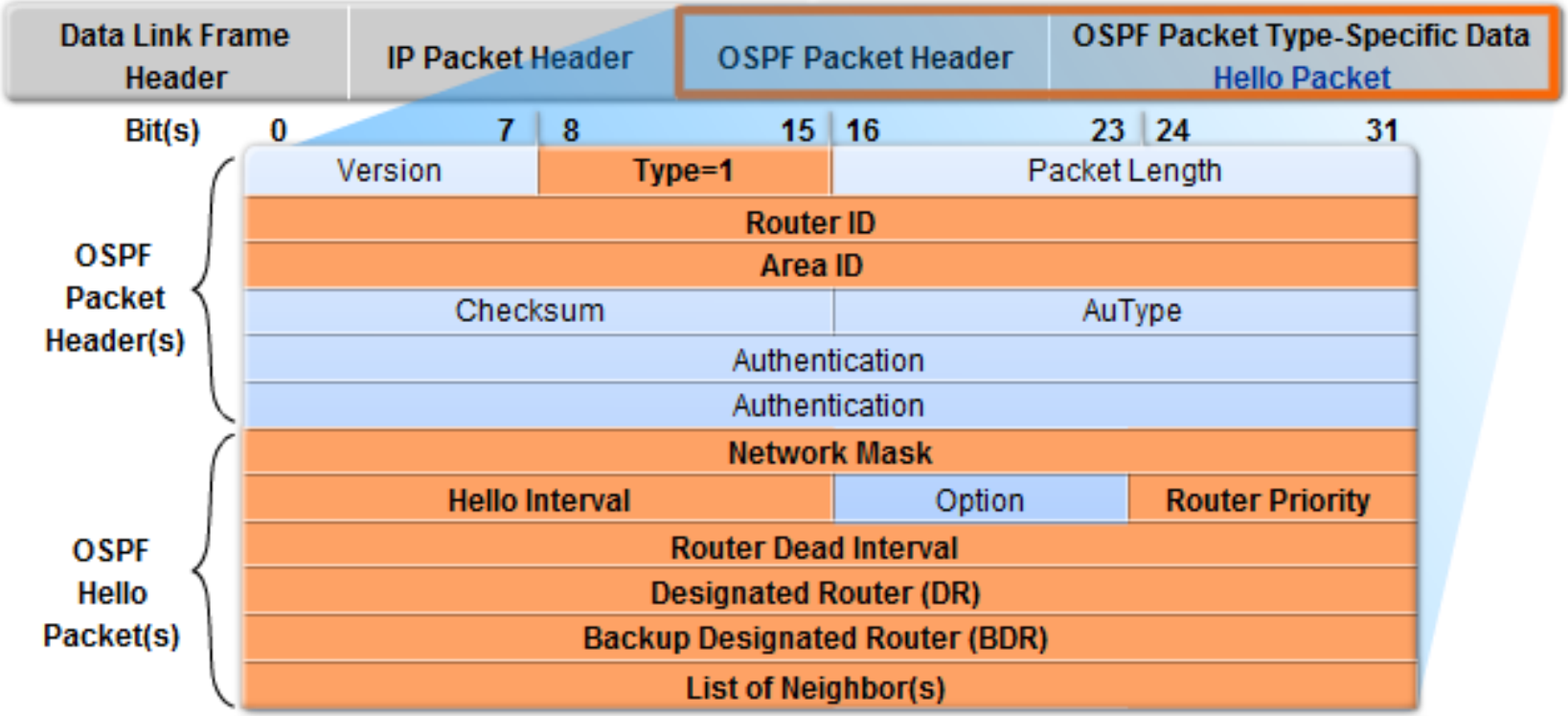
OSFP Neighbors

- OSPF uses hello packets to create adjacencies and maintain connectivity with neighbor routers
- OSPF uses the multicast address 224.0.0.5



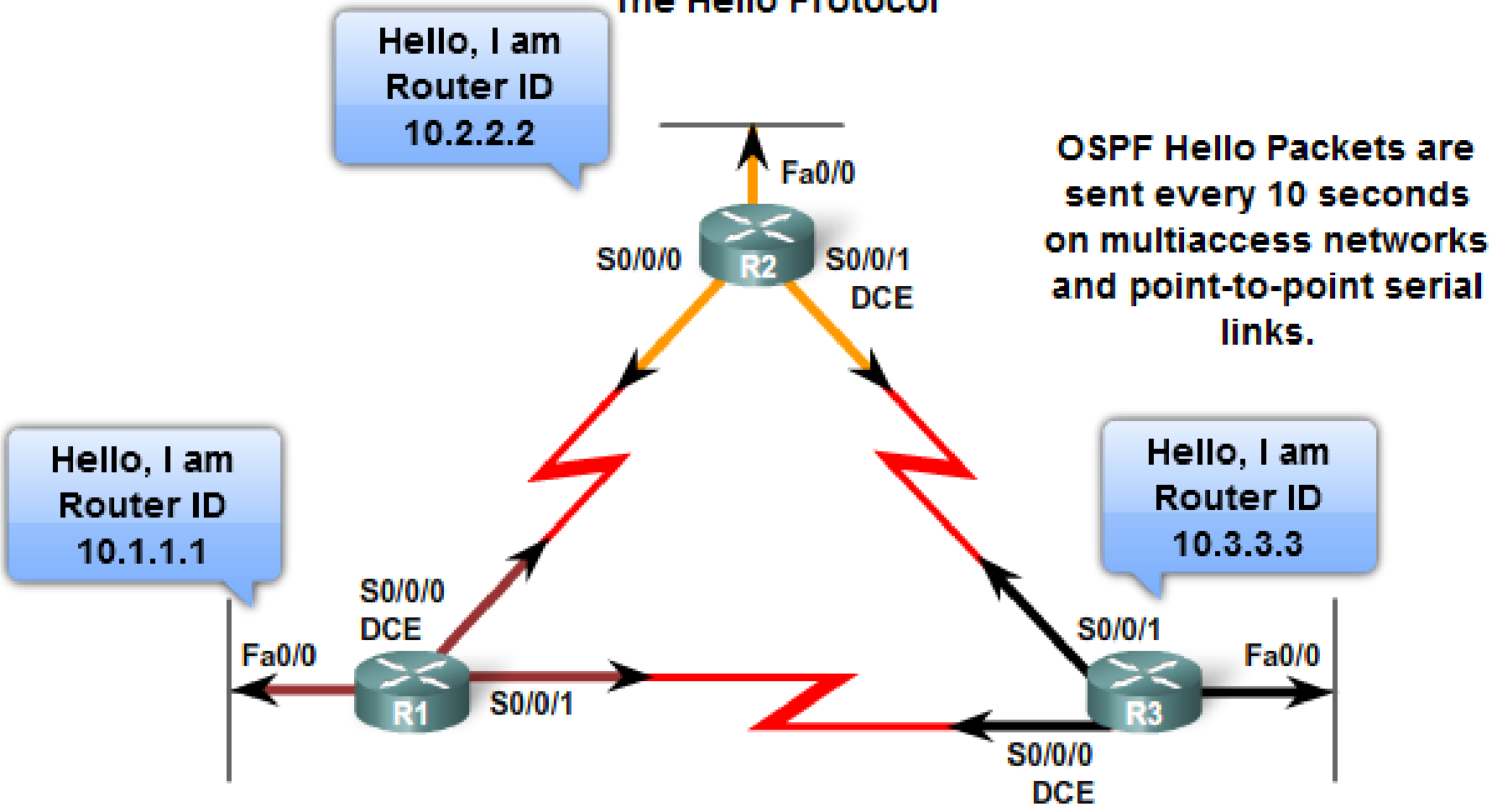
•Hello packets provides dynamic neighbor discovery
•Hello Packets maintains neighbor relationships
•Hello packets and LSA's from other routers help build and maintain the topological database

Hello message



- **Type**: OSPF Packet Type: Hello (1), DD (2), LS Request (3), LS Update (4), LS ACK (5)
- **Router ID**: ID of the originating router
- **Area ID**: area from which the packet originated
- **Network Mask**:Subnet mask associated with the sending interface
- **Hello Interval**:number of seconds between the sending router's hellos
- **Router Priority**: Used in DR/BDR election (discussed later)
- **Designated Router (DR)**:Router ID of the DR, if any
- **Backup Designated Router (BDR)**:Router ID of the BDR, if any
- **List of Neighbors**: lists the OSPF Router ID of the neighboring router(s)

The Hello Protocol



OSPF Hello Packets are sent every 10 seconds on multiaccess networks and point-to-point serial links.

Matching interface values for two routers to form an adjacency

Hello Interval = Hello Interval
Dead Interval = Dead Interval
Network Type = Network Type

LSUs Contain Link-State Advertisements (LSAs)

Type	Packet Name	Description
1	Hello	Discovers neighbors and builds adjacencies between them
2	DBD	Checks for database synchronization between router
3	LSR	Requests specific link-state records from router to router
4	LSU	Sends specifically requested link-state records
5	LSAck	Acknowledges the other packet types

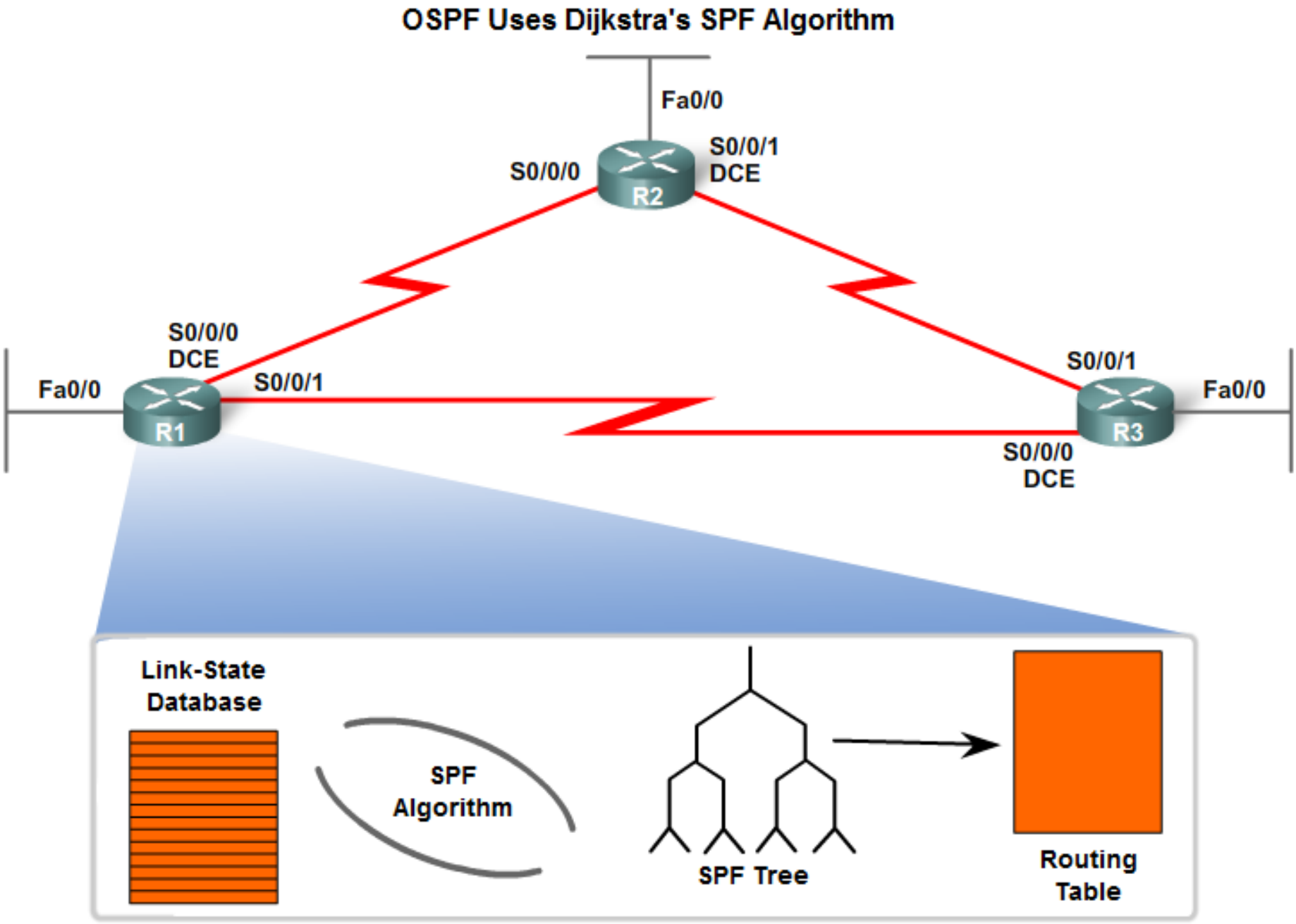
The acronyms LSA and LSU are often used interchangeably.

An LSU contains one or more LSAs.

LSAs contain route information for destination networks.

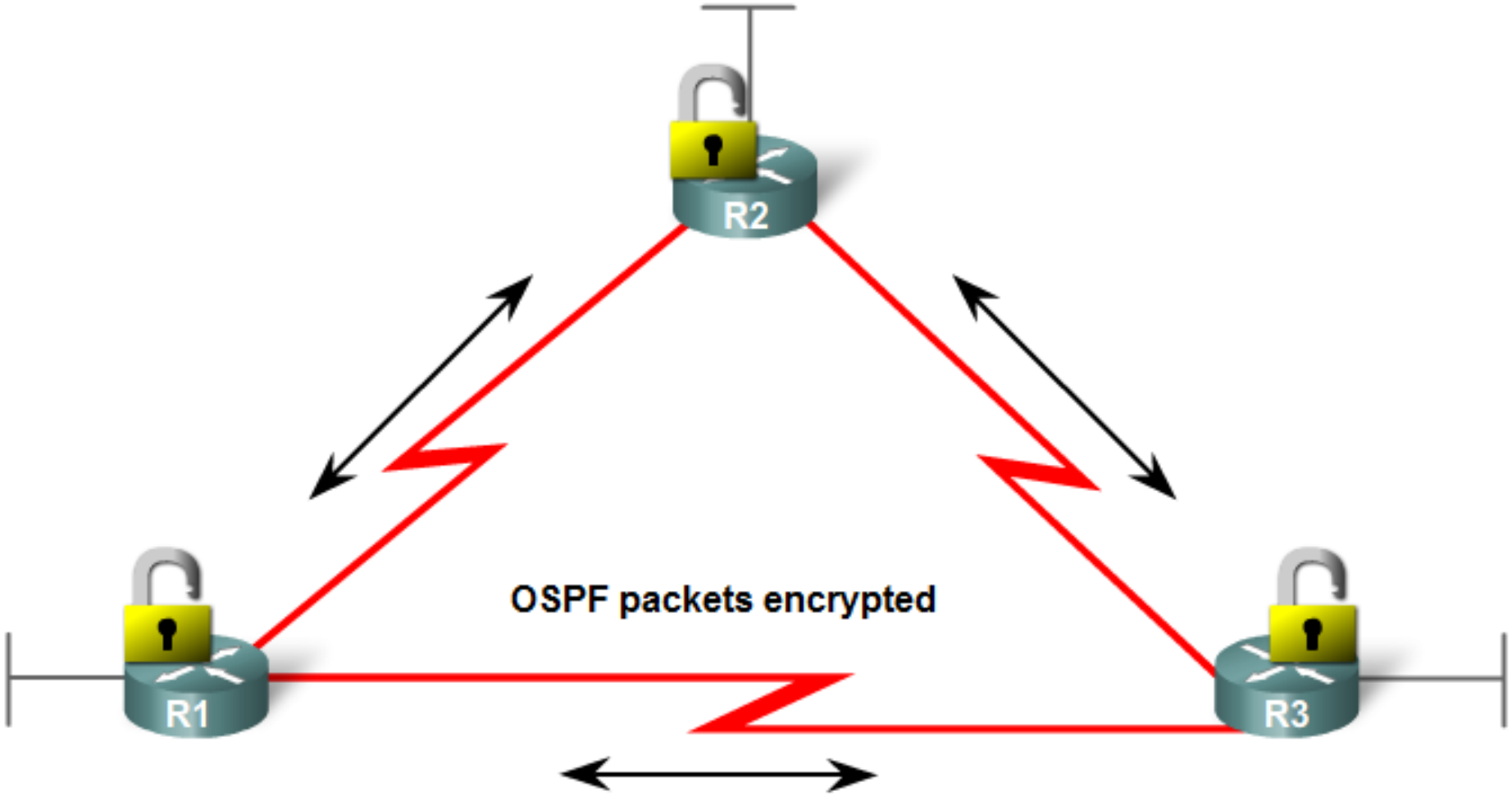
LSA specifics are discussed in CCNP.

LSA Type	Description
1	Router LSAs
2	Network LSAs
3 or 4	Summary LSAs
5	Autonomous System Extrenal LSAs
6	Multicast OSPF LSAs
7	Defined for Not-So-Stubby Areas
8	External Attributes LSA for Border Gatway Protocol(BGP)
9,10,11	Opaque LSAs


OSPF Uses Dijkstra's SPF Algorithm
Fa0/0
S0/0/0
S0/0/1
DCE
R2
S0/0/0
DCE
Fa0/0
S0/0/1
R1
S0/0/1
Fa0/0
S0/0/0
DCE
R3
Link-State
Database
SPF
Algorithm
SPF Tree
Routing
Table

Route Source	Administrative Distance
Connected	0
Static	1
EIGRP summary route	5
External BGP	20
Internal EIGRP	90
IGRP	100
OSPF	110
IS-IS	115
RIP	120
External EIGRP	170
Internal BGP	200

Authentication



Configuring Single Area OSPF

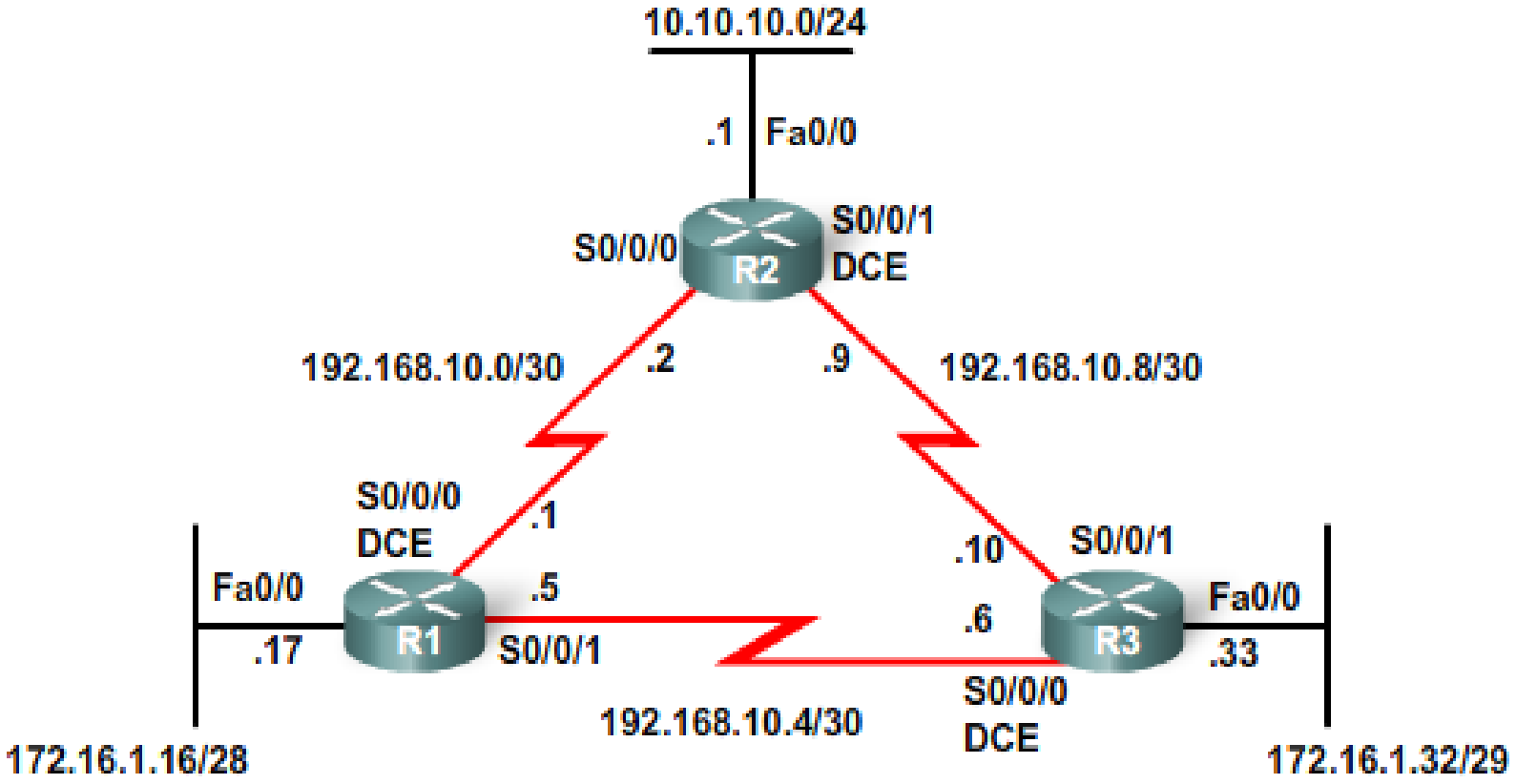
```
Router(config)#router ospf process-id
```

Defines OSPF as the IP routing protocol

Note: The process ID is locally significant and is needed to identify a unique instance of an OSPF database

```
Router(config-router)#network address mask area area-id
```

Assigns networks to a specific OSPF area


10.10.10.0/24
.1
Fa0/0
S0/0/0
R2
S0/0/1
DCE
192.168.10.0/30
.2
.9
192.168.10.8/30
S0/0/0
DCE
.1
.10
S0/0/1
Fa0/0
.5
.6
Fa0/0
.17
R1
S0/0/1
R3
.33
S0/0/0
DCE
192.168.10.4/30
172.16.1.16/28
172.16.1.32/29

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

```
R2(config)#router ospf 1
R2(config-router)#
```

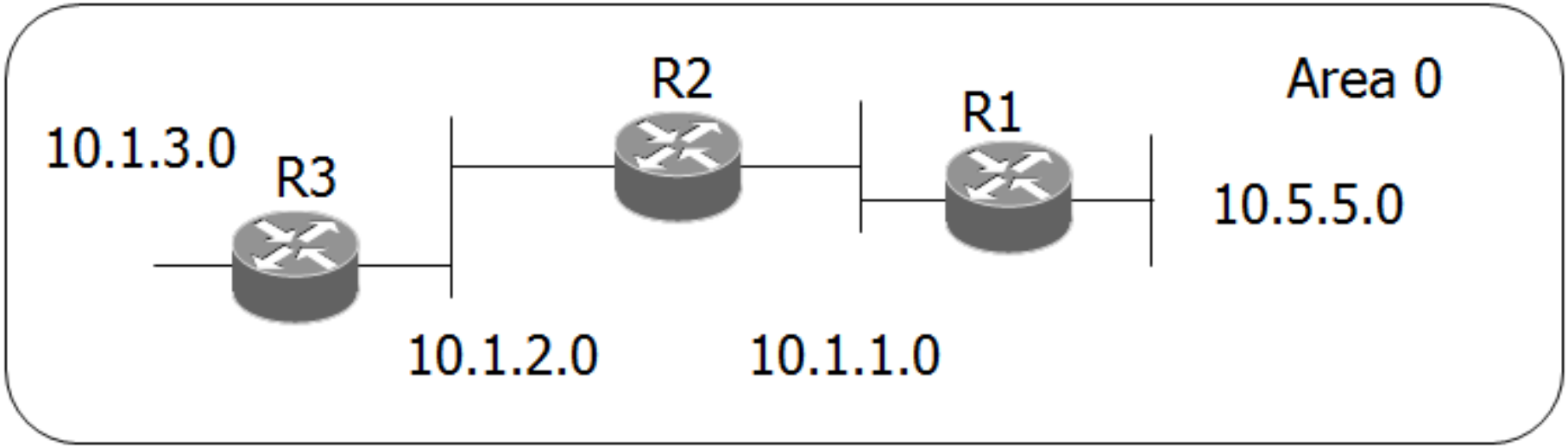
```
R3(config)#router ospf 1
R3(config-router)#
```

```
R1(config)#router ospf 1
R1(config-router)#network 172.16.1.16 0.0.0.15 area 0
R1(config-router)#network 192.168.10.0 0.0.0.3 area 0
R1(config-router)#network 192.168.10.4 0.0.0.3 area 0
```

```
R2(config)#router ospf 1
R2(config-router)#network 10.10.10.0 0.0.0.255 area 0
R2(config-router)#network 192.168.10.0 0.0.0.3 area 0
R2(config-router)#network 192.168.10.8 0.0.0.3 area 0
```

```
R3(config)#router ospf 1
R3(config-router)#network 172.16.1.32 0.0.0.7 area 0
R3(config-router)#network 192.168.10.4 0.0.0.3 area 0
R3(config-router)#network 192.168.10.8 0.0.0.3 area 0
```

OSPF Example



hostname R3	**hostname R2**	**hostname R1**
router ospf 10 network 10.1.2.3 0.0.0.0 area 0 network 10.1.3.1 0.0.0.0 area 0	router ospf 20 network 10.0.0.0 0.255.255.255 area 0	router ospf 30 network 10.1.0.0 0.0.255.255 area 0 network 10.5.5.1 0.0.0.0 area 0

Verifying the OSPF Configuration

```
Router#show ip protocols
```

Verifies that OSPF is configured

```
Router#show ip route
```

Displays all the routes learned by the router

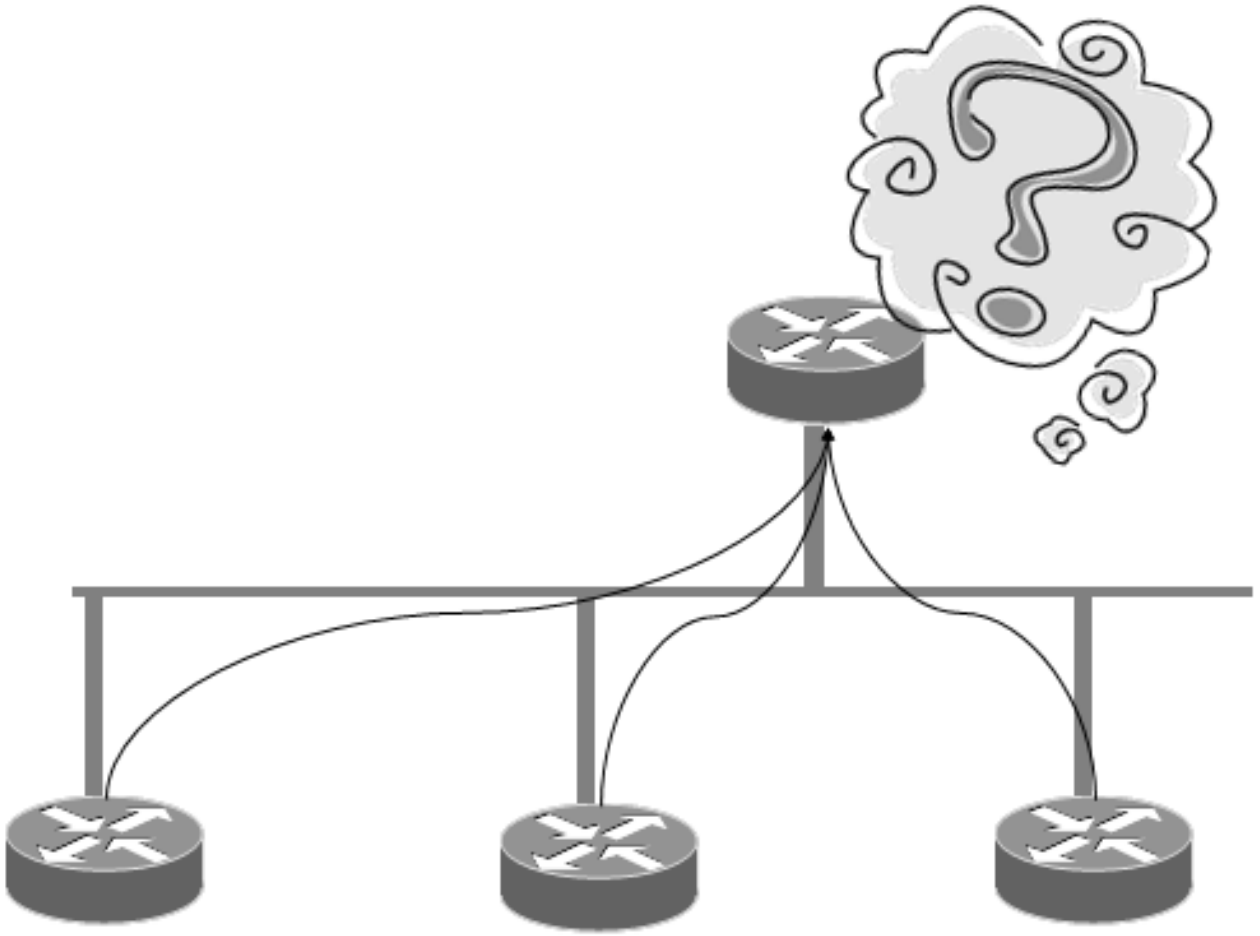
```
Router#show ip ospf interface
```

Displays area-ID and adjacency information

```
Router#show ip ospf neighbor
```

Displays OSPF-neighbor information on a per-interface basis

Router ID (RID)



Each router in OSPF needs to be uniquely identified to properly arrange them in the Neighbor tables.

Router ID is determined in the following order:

1. Use the IP address configured with the OSPF router-id command.
2. If the router-id is not configured, then the router chooses highest IP address of any of its loopback interfaces.
3. If no loopback interfaces are configured, then the router chooses highest active IP address of any of its physical interfaces.

```
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 192.168.10.5
  Number of areas in this router is 1. 1 normal 0 stub 0 nssa
```

```
R2#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 192.168.10.9
  Number of areas in this router is 1. 1 normal 0 stub 0 nssa
```

```
R3#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 192.168.10.10
  Number of areas in this router is 1. 1 normal 0 stub 0 nssa
```

```
R1(config)#interface loopback 0
R1(config-if)#ip add 10.1.1.1 255.255.255.255
```

```
R2(config)#interface loopback 0
R2(config-if)#ip add 10.2.2.2 255.255.255.255
```

```
R3(config)#interface loopback 0
R3(config-if)#ip add 10.3.3.3 255.255.255.255
```

```
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 10.1.1.1
  Number of areas in this router is 1. 1 normal 0 stub 0 nssa
```

```
R2#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 10.2.2.2
  Number of areas in this router is 1. 1 normal 0 stub 0 nssa
```

```
R3#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 10.3.3.3
  Number of areas in this router is 1. 1 normal 0 stub 0 nssa
```

```
R1#show ip ospf neighbor

Neighbor ID     Pri   State           Dead Time   Address         Interface
10.3.3.3          1   FULL/  -        00:00:30    192.168.10.6    Serial0/0/1
10.2.2.2          1   FULL/  -        00:00:33    192.168.10.2    Serial0/0/0
```

```
R2#show ip ospf neighbor

Neighbor ID     Pri   State           Dead Time   Address         Interface
10.3.3.3          1   FULL/  -        00:00:36    192.168.10.10   Serial0/0/1
10.1.1.1          1   FULL/  -        00:00:37    192.168.10.1    Serial0/0/0
```

```
R3#show ip ospf neighbor

Neighbor ID     Pri   State           Dead Time   Address         Interface
10.2.2.2          1   FULL/  -        00:00:34    192.168.10.9    Serial0/0/1
10.1.1.1          1   FULL/  -        00:00:38    192.168.10.5    Serial0/0/0
```

```
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 10.1.1.1
  Number of areas in this router is 1. 1 normal 0 stub 0 nssa
  Maximum path: 4
  Routing for Networks:
    172.16.1.16 0.0.0.15 area 0
    192.168.10.0 0.0.0.3 area 0
    192.168.10.4 0.0.0.3 area 0
 Reference bandwidth unit is 100 mbps
  Routing Information Sources:
    Gateway         Distance      Last Update
    10.2.2.2              110      11:29:29
    10.3.3.3              110      11:29:29
  Distance: (default is 110)
```

```
R1#show ip ospf
 <some output omitted>
 Routing Process "ospf 1" with ID 10.1.1.1
 Start time: 00:00:19.540, Time elapsed: 11:31:15.776
 Supports only single TOS(TOS0) routes
 Supports opaque LSA
 Supports Link-local Signaling (LLS)
 Supports area transit capability
 Router is not originating router-LSAs with maximum metric
 Initial SPF schedule delay 5000 msecs
 Minimum hold time between two consecutive SPFs 10000 msecs
 Maximum wait time between two consecutive SPFs 10000 msecs
 Incremental-SPF disabled
 Minimum LSA interval 5 secs
 Minimum LSA arrival 1000 msecs
 Area BACKBONE(0)
        Number of interfaces in this area is 3
        Area has no authentication
        SPF algorithm last executed 11:30:31.628 ago
```

```
R1#show ip ospf interface serial 0/0/0
Serial0/0/0 is up, line protocol is up
  Internet Address 192.168.10.1/30, Area 0
  Process ID 1, Router ID 10.1.1.1, Network Type POINT_TO_POINT, Cost: 64
  Transmit Delay is 1 sec, State POINT_TO_POINT,
  Timer intervals configured, Hello 10, Dead 40, Wait 40, Retransmit 5
    oob-resync timeout 40
    Hello due in 00:00:07
  Supports Link-local Signaling (LLS)
  Index 2/2, flood queue length 0
  Next 0x0(0)/0x0(0)
  Last flood scan length is 1, maximum is 1
  Last flood scan time is 0 msec, maximum is 4 msec
  Neighbor Count is 1, Adjacent neighbor count is 1
    Adjacent with neighbor 10.2.2.2
  Suppress hello for 0 neighbor(s)
```

```
R1#show ip route

Codes: <some code output omitted>
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area

Gateway of last resort is not set

     192.168.10.0/30 is subnetted, 3 subnets
C       192.168.10.0 is directly connected, Serial0/0/0
C       192.168.10.4 is directly connected, Serial0/0/1
O       192.168.10.8 [110/128] via 192.168.10.2, 14:27:57, Serial0/0/0
     172.16.0.0/16 is variably subnetted, 2 subnets, 2 masks
O       172.16.1.32/29 [110/65] via 192.168.10.6, 14:27:57, Serial0/0/1
C       172.16.1.16/28 is directly connected, FastEthernet0/0
     10.0.0.0/8 is variably subnetted, 2 subnets, 2 masks
O       10.10.10.0/24 [110/65] via 192.168.10.2, 14:27:57, Serial0/0/0
C       10.1.1.1/32 is directly connected, Loopback0
```

```
R2#show ip route

Codes: <some code output omitted>
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area

Gateway of last resort is not set

     192.168.10.0/30 is subnetted, 3 subnets
C       192.168.10.0 is directly connected, Serial0/0/0
O       192.168.10.4 [110/128] via 192.168.10.1, 14:31:18, Serial0/0/0
C       192.168.10.8 is directly connected, Serial0/0/1
     172.16.0.0/16 is variably subnetted, 2 subnets, 2 masks
O       172.16.1.32/29 [110/65] via 192.168.10.10, 14:31:18, Serial0/0/1
O       172.16.1.16/28 [110/65] via 192.168.10.1, 14:31:18, Serial0/0/0
     10.0.0.0/8 is variably subnetted, 2 subnets, 2 masks
C       10.2.2.2/32 is directly connected, Loopback0
C       10.10.10.0/24 is directly connected, FastEthernet0/0
```

```
R3#show ip route

Codes: <some code output omitted>
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area

Gateway of last resort is not set

     192.168.10.0/30 is subnetted, 3 subnets
O       192.168.10.0 [110/845] via 192.168.10.9, 14:31:52, Serial0/0/1
                     [110/845] via 192.168.10.5, 14:31:52, Serial0/0/0
C       192.168.10.4 is directly connected, Serial0/0
C       192.168.10.8 is directly connected, Serial0/1
     172.16.0.0/16 is variably subnetted, 2 subnets, 2 masks
C       172.16.1.32/29 is directly connected, FastEthernet0/0
O       172.16.1.16/28 [110/782] via 192.168.10.5, 14:31:52, Serial0/0/0
     10.0.0.0/8 is variably subnetted, 2 subnets, 2 masks
C       10.3.3.3/32 is directly connected, Loopback0
O       10.10.10.0/24 [110/782] via 192.168.10.9, 14:31:52, Serial0/0/1
```

Practice 01