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Outline

- Overview
- OSPF Features
- OSPF and Distance Vector Routing Protocol Comparison
- Hierarchical Routing
- Shortest Path First Algorithm
- Single-Area OSPF Configuration
- Loopback Interfaces
- OSPF Configuration Verification
- OSPF Configuration Troubleshooting
- Summary

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OSPF

- Open Shortest Path First
- Link State or SPF technology
- Developed by the IETF's OSPF working group (RFC 1247)
- Designed for TCP/IP
- Fast Convergence
- Variable length netmasks
- Non-contiguous subnets
- No need for periodic updates
- Route authentication
- OSPF is defined in RFC2328

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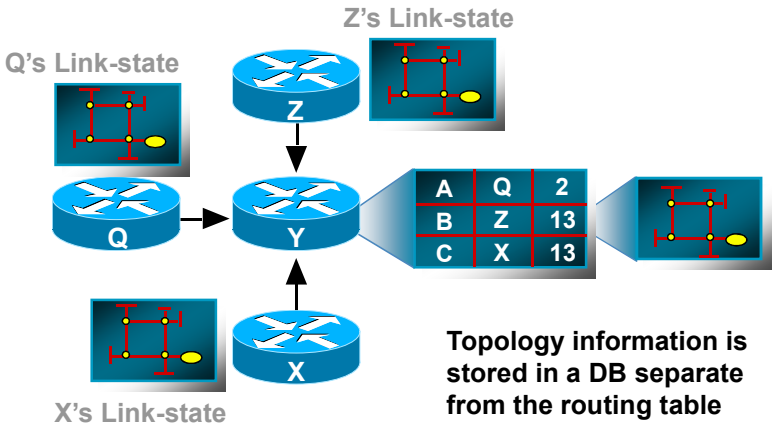
Link-State



Topology information is stored in a DB separate from the routing table

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Link-State Routing

- Neighbor discovery
- Construct a Link State Packet (LSP)
- Distribute the LSP
  - Link State Announcement – LSA
- Route calculation
- If a link fails
  - Flood new LSPs
  - All routers recalculate their routing tables

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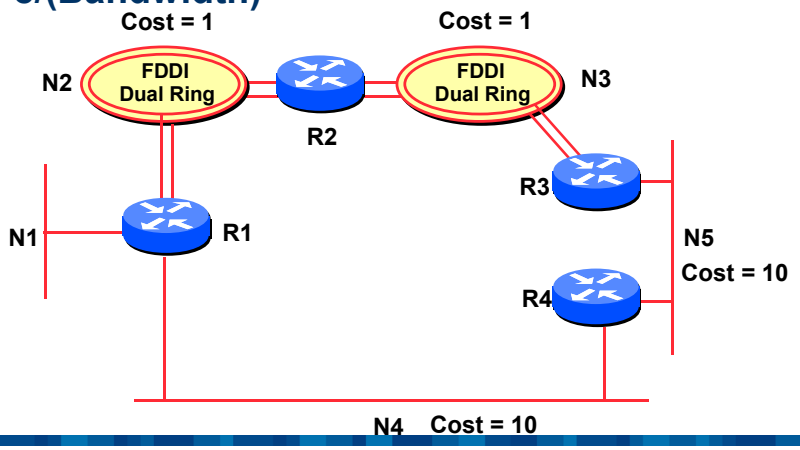
Using the Optimal Path

The optimal path is determined by adding the costs of the interfaces : Cost = 10^8/(Bandwidth)



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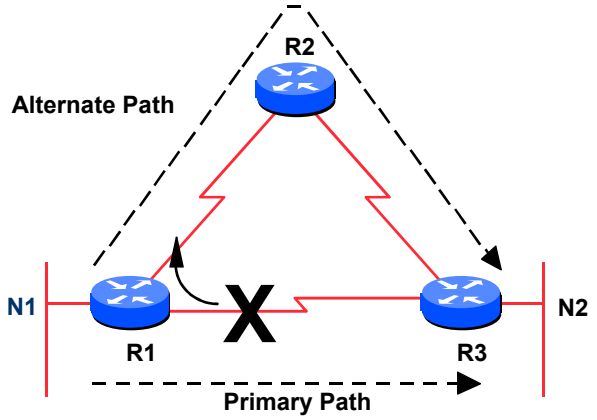
Fast Convergence

Detection plus LSA/SPF



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Uses IP Multicast to Send/Receive changes

Multi-Access networks

- All routers must accept packets sent to the AllSPFRouters (224.0.0.5) address
- All DR and BDR routers must accept packets sent to the AllDRouters (224.0.0.6) address

Hello packets are sent to the AllSPFRouters address (Unicast for point-to-point and virtual links)

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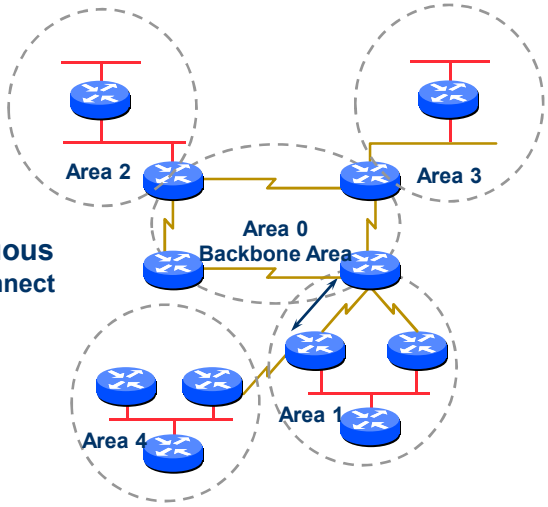
OSPF Areas

- Group of contiguous nodes/networks
- Per area topology DB
  - Invisible outside the area
  - Reduces routing traffic
- Backbone Area is contiguous
  - All others areas must connect to the backbone
- Virtual Links



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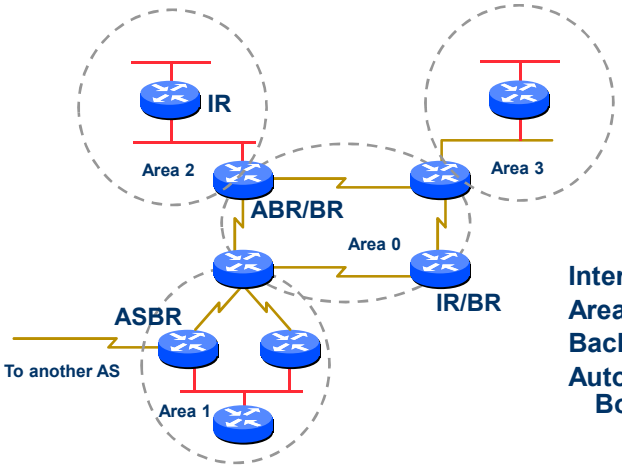
Router Classification



- Internal Router (IR)
- Area Border Router (ABR)
- Backbone Router (BR)
- Autonomous System Border Router (ASBR)

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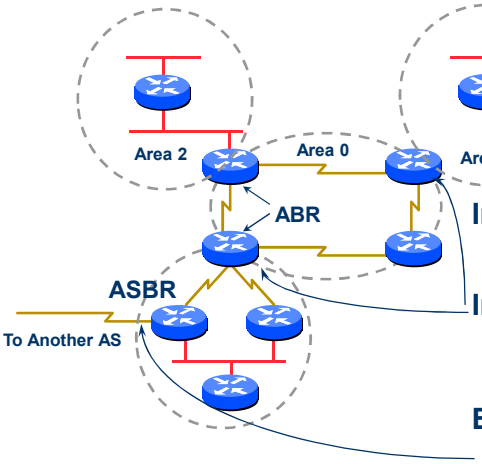
OSPF Route Types



Intra-Area Route
- All routes within an area

Inter-Area Route
- Routes announced from area to another by an ABR

External Route
- Routes imported into OSPF from another protocol or Static routes

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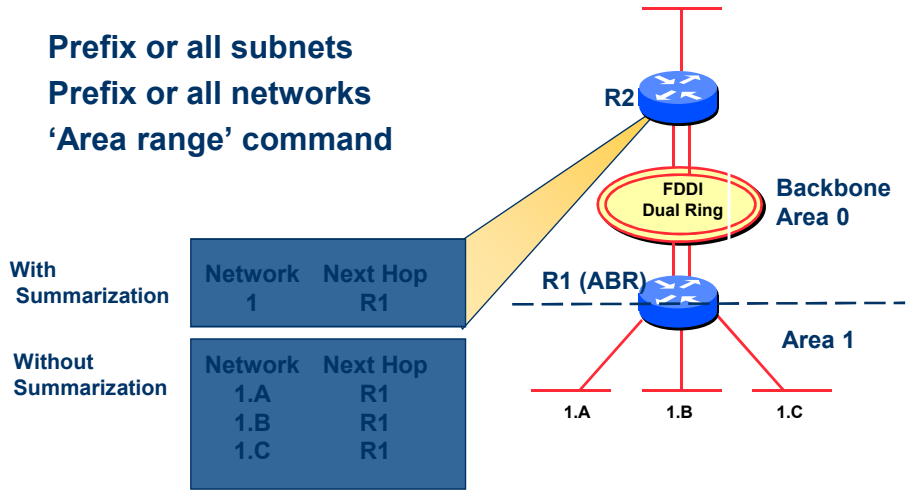
Inter-Area Route Summarization

Prefix or all subnets
Prefix or all networks
'Area range' command



With Summarization

Network	Next Hop
1	R1

Without Summarization

Network	Next Hop
1.A	R1
1.B	R1
1.C	R1

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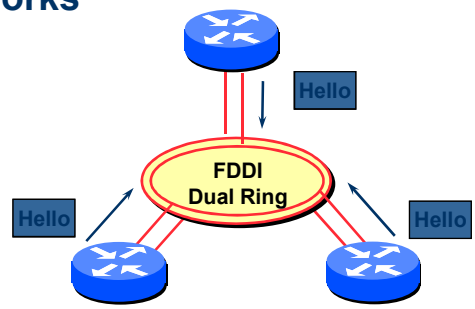
The Hello Protocol

- Responsible to establish and maintain neighbor relationships
- Elects designated router in multi-access networks



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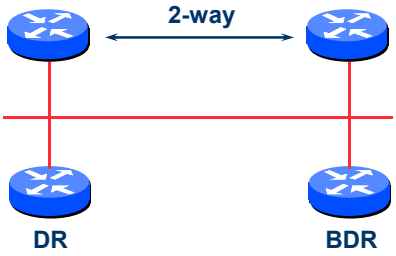
Neighbor States

2-way

- The router sees itself in other Hello packets
- DR is selected from neighbors in state 2-way or greater



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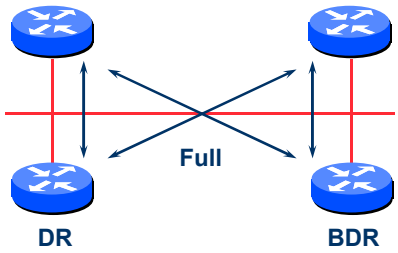
Neighbor States

Full

- Routers are fully adjacent
- DB is synchronized
- Relationship to the DR and BDR



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OSPF – Adding Networks

Specific network statements

- Each interface requires an OSPF network statement. Interfaces that should not bet broadcasting Hello packets need a passive-interface statement
  - `router ospf 100`
  - `network 192.168.1.1 0.0.0.3 area 51`
  - `network 192.168.1.5 0.0.0.3 area 51`
  - `passive interface Serial 1/0`

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OSPF – Adding Networks

Network statements - wildcard mask

- Every interface covered by a wildcard mask used in the OSPF network statement.
  - `router ospf 100`
  - `network 192.168.1.0 0.0.0.255 area 51`

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OSPF – Adding Networks

The key theme when selecting which method to use is to keep the links-state DB as small as possible

- Increases stability
- Reduces the amount of information in the LSAs
- Speeds up convergence time

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Configuring Single-Area OSPF

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

- Defines OSPF as the IP routing protocol

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

- Assigns networks to a specific OSPF area

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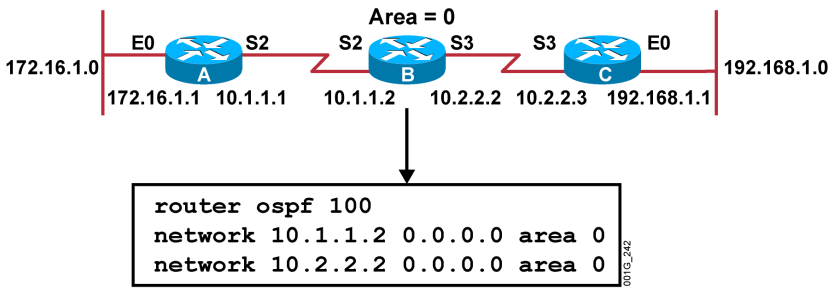
OSPF Configuration Example



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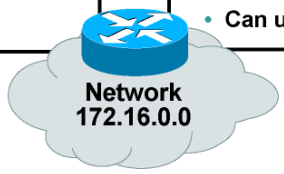
Configuring Loopback Interfaces

Unadvertised Loopback Address
Ex: 192.168.255.254
- Not in OSPF table
- Saves address space
- Cannot use ping

Advertised Loopback Address
Ex: 172.16.17.5
- In OSPF table
- Uses address space
- Can use ping



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Router ID
- Number by which the router is known to OSPF
- Default: The highest IP address on an active interface at the moment of OSPF process startup
- Can be overridden by a loopback interface: Highest IP address of any active loopback interface
- Can be set manually using the router-id command

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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 route

Codes: I - IGRP derived, R - RIP derived, O - OSPF derived,
C - connected, S - static, E - EGP derived, B - BGP derived,
E2 - OSPF external type 2 route, N1 - OSPF NSSA external type 1 route,
N2 - OSPF NSSA external type 2 route

Gateway of last resort is 10.119.254.240 to network 10.140.0.0

O E2 10.110.0.0 [160/5] via 10.119.254.6, 0:01:00, Ethernet2
E 10.67.10.0 [200/128] via 10.119.254.244, 0:02:22, Ethernet2
O E2 10.68.132.0 [160/5] via 10.119.254.6, 0:00:59, Ethernet2
O E2 10.130.0.0 [160/5] via 10.119.254.6, 0:00:59, Ethernet2
E 10.128.0.0 [200/128] via 10.119.254.244, 0:02:22, Ethernet2
```


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Verifying the OSPF Configuration (Cont.)

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

- Displays OSPF neighbor information on a per-interface basis

```
Router# show ip ospf neighbor

ID Pri State Dead Time Address Interface
10.199.199.137  1 FULL/DR 0:00:31 192.168.80.37 Ethernet0
172.16.48.1 1 FULL/DROTHER 0:00:33 172.16.48.1  Fddi0
172.16.48.200 1 FULL/DROTHER 0:00:33 172.16.48.200  Fddi0
10.199.199.137  5 FULL/DR 0:00:33 172.16.48.189  Fddi0
```


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OSPF debug Commands

```
Router# debug ip ospf events

OSPF:hello with invalid timers on interface Ethernet0
hello interval received 10 configured 10
net mask received 255.255.255.0 configured 255.255.255.0
dead interval received 40 configured 30
Router# debug ip ospf packet

OSPF: rcv. v:2 t:1 l:48 rid:200.0.0.117
      aid:0.0.0.0 chk:6AB2 aut:0 auk:

Router# debug ip ospf packet

OSPF: rcv. v:2 t:1 l:48 rid:200.0.0.116
      aid:0.0.0.0 chk:0 aut:2 keyid:1 seq:0x0
```


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MULTI-AREA OSPF

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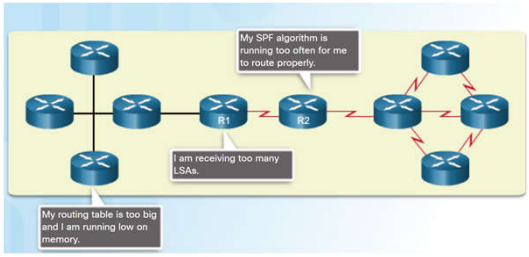
Why Multiarea OSPF?
Single-Area OSPF

Issues in a large single area OSPF:

- **Large routing table**
- **Large link-state database (LSDB)**
- **Frequent SPF algorithm calculations**

To make OSPF more efficient and scalable, OSPF supports hierarchical routing using areas.



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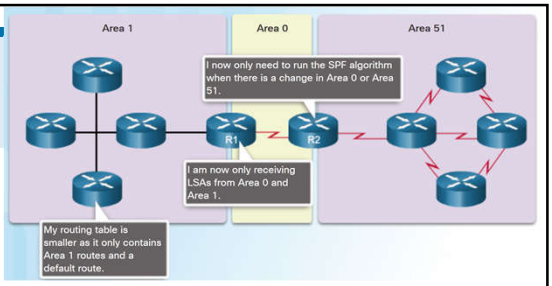
Why Multiarea OSPF?

Multiarea OSPF



Multiarea OSPF:

- Large OSPF area is divided into smaller areas.
- Reduces processing and memory overhead.
- Requires a hierarchical network design.
- The main area is the backbone area (area 0) and all other areas connect to it.

Advantages of Multiarea OSPF:

- Smaller routing tables - Fewer routing table entries as network addresses can be summarized between areas.
- Reduced link-state update overhead.

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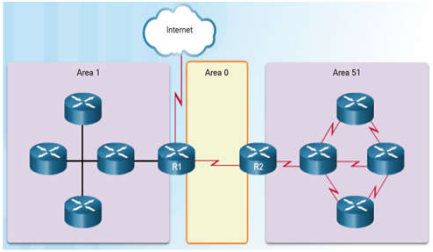
Why Multiarea OSPF?

OSPF Two-Layer Area Hierarchy



Multiarea OSPF is implemented in a two-layer area hierarchy.

Backbone (Transit) area - An OSPF area whose primary function is the fast and efficient movement of IP packets:

- Interconnects with other OSPF area types.
- Also called OSPF area 0.

Regular (nonbackbone) area - Connects users and resources:

- Usually set up along functional or geographical

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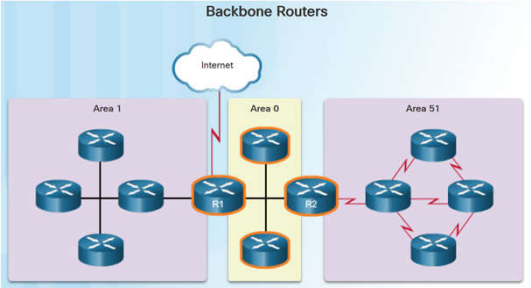
Why Multiarea OSPF?

Types of OSPF Routers



There are four different types of OSPF routers:

- Internal router –A router that has all of its interfaces in the same area.
- Backbone router - A router in the backbone area. The backbone area is set to area 0
- Area Border Router (ABR) – A router that has interfaces attached to multiple areas.
- Autonomous System Boundary Router (ASBR) – A router that has at least one interface attached to an external internetwork.

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Multiarea OSPF LSA Operation

OSPF LSA Types

LSA Type	Description
1	Router LSA
2	Network LSA
3 and 4	Summary LSAs
5	AS External LSA
6	Multicast OSPF LSA
7	Defined for NSSAs
8	External Attributes LSA for Border Gateway Protocol (BGP)
9, 10, or 11	Opaque LSAs

LSAs individually act as database records and provide specific OSPF network details.

LSAs in combination describe the entire topology of an OSPF network or area.

Any implementation of multiarea OSPF must support the first five LSAs

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OSPF Routing Table and Types of Routes

OSPF Routing Table Entries

```
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
       i - IS-IS, su - IS-IS summary, 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, H - NHRP, l - LISP
       + - replicated route, % - next hop override

Gateway of last resort is 192.168.10.2 to network 0.0.0.0

O*E2 0.0.0.0/0 [110/1] via 192.168.10.2, 00:00:19, Serial0/0/0
     10.0.0.0/8 is variably subnetted, 5 subnets, 2 masks
C       10.1.1.0/24 is directly connected, GigabitEthernet0/0
L       10.1.1.1/32 is directly connected, GigabitEthernet0/0
C       10.1.2.0/24 is directly connected, GigabitEthernet0/1
L       10.1.2.1/32 is directly connected, GigabitEthernet0/1
O       10.2.1.0/24 [110/648] via 192.168.10.2, 00:04:34, Serial0/0/0
O IA 192.168.1.0/24 [110/1295] via 192.168.10.2, 00:01:48, Serial0/0/0
O IA 192.168.2.0/24 [110/1295] via 192.168.10.2, 00:01:48, Serial0/0/0
     192.168.10.0/24 is variably subnetted, 3 subnets, 2 masks
C       192.168.10.0/30 is directly connected, Serial0/0/0
L       192.168.10.1/32 is directly connected, Serial0/0/0
O       192.168.10.4/30 [110/1294] via 192.168.10.2, 00:01:55, Serial0/0/0
R1#
```

- OSPF routes in an IPv4 routing table are identified using the following descriptors:
  - O - The routing table reflects the link-state information with a designation of O, meaning that the route is intra-area
  - O IA - Summary LSAs appear in the routing table as IA (interarea routes).
  - O E1 or O E2 - External LSAs appear in the routing table marked as external type 1 (E1) or external type 2 (E2) routes.

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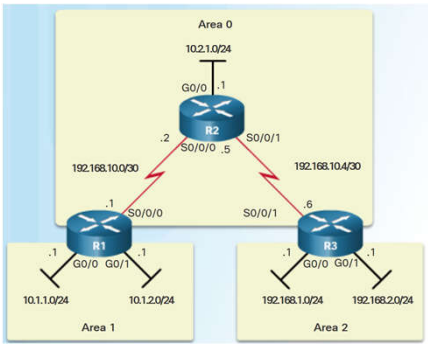
Configuring Multiarea OSPF

Configuring Multiarea OSPFv2




```
R1(config)# router ospf 10
R1(config-router)# router-id 1.1.1.1
R1(config-router)# network 10.1.1.1 0.0.0.0 area 1
R1(config-router)# network 10.1.2.1 0.0.0.0 area 1
R1(config-router)# network 192.168.10.1 0.0.0.0 area 0
R1(config-router)# end
R1#
```

- There are no special commands to implement multiarea OSPFv2.
- A router becomes an ABR when it has two network statements in different areas.
- R1 is an ABR because it has interfaces in area 1 and an interface in area 0.

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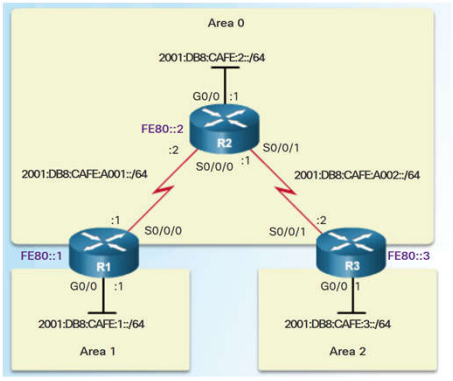
Configuring Multiarea OSPF

Configuring Multiarea OSPFv3




```
R1(config)# ipv6 router ospf 10
R1(config-rtr)# router-id 1.1.1.1
R1(config-rtr)# exit
R1(config)#
R1(config)# interface GigabitEthernet 0/0
R1(config-if)# ipv6 ospf 10 area 1
R1(config-if)#
R1(config-if)# interface Serial0/0/0
R1(config-if)# ipv6 ospf 10 area 0
R1(config-if)# end
R1#
```

- There are no special commands required to implement multiarea OSPFv3.
- A router becomes an ABR when it has two interfaces in different areas.

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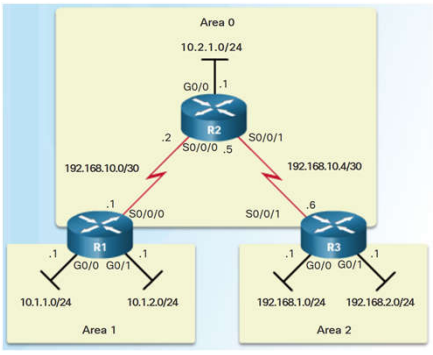
Verifying Multiarea OSPF

Verifying Multiarea OSPFv2

Commands to verify multiarea OSPFv2

- show ip ospf neighbor
- show ip ospf
- show ip ospf interface
- Show ip protocols
- show ip ospf interface brief
- show ip route ospf
- show ip ospf database

Note: For the equivalent OSPFv3 command



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Summary

- OSPF is an interior gateway protocol similar to IGRP, but based on link states rather than distance vectors.
- OSPF advertises information about each of its links rather than sending routing table updates like a distance vector protocol does.
- Hierarchical routing enables separation of a large internetwork into smaller internetworks, called areas.
- The SPF algorithm places each router at the root of a tree and calculates the shortest path to each destination based on the cumulative cost required to reach that destination.

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