Configuration and Management of Networks

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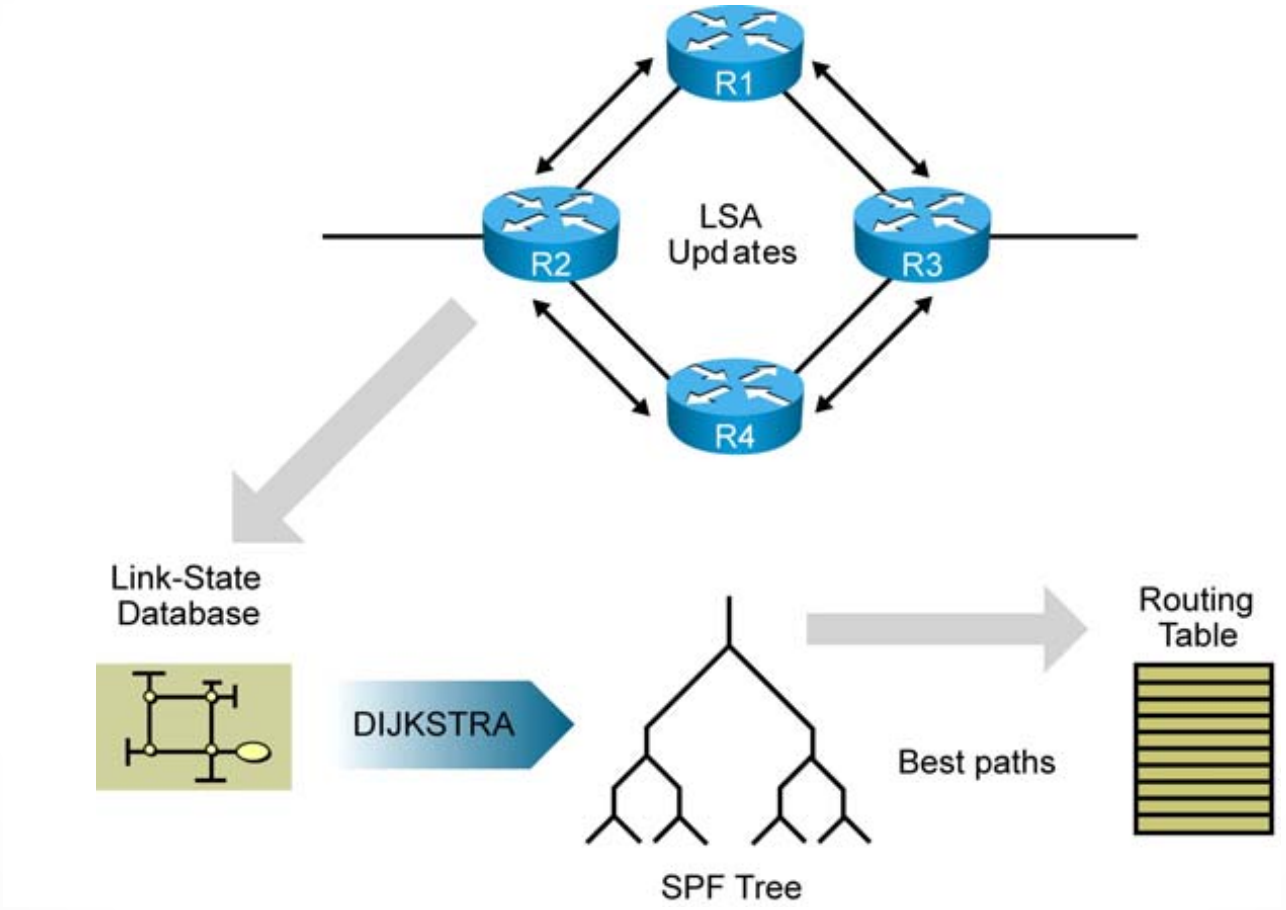
Link State Protocols

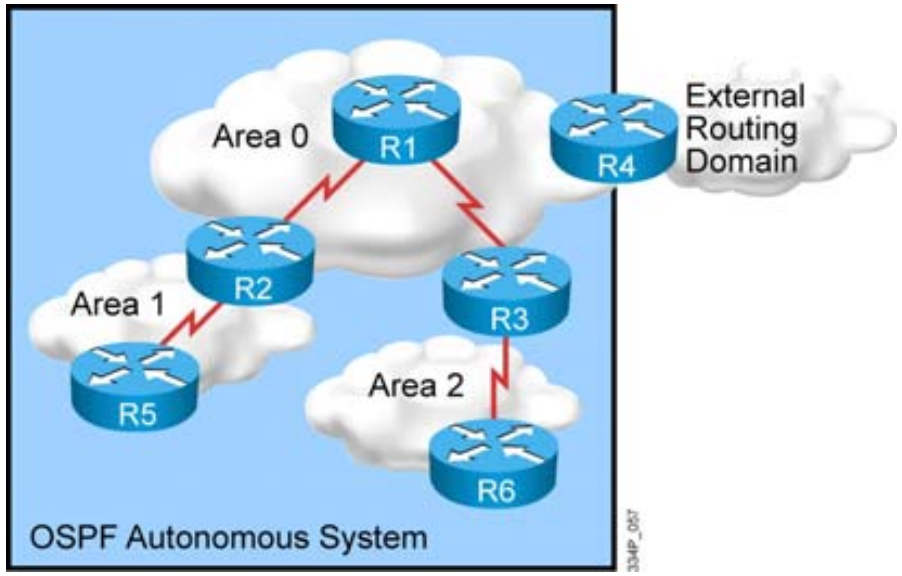


Link State Protocols

- Link-state routers recognize more information about the network than their distance vector counterparts.
  - **Neighbor table:** also known as the adjacency database
  - **Topology table:** referred as the LSDB
  - **Routing table:** also known as the forwarding database
- Each router has a full picture of the topology
- Link-state routers tend to make more accurate decisions

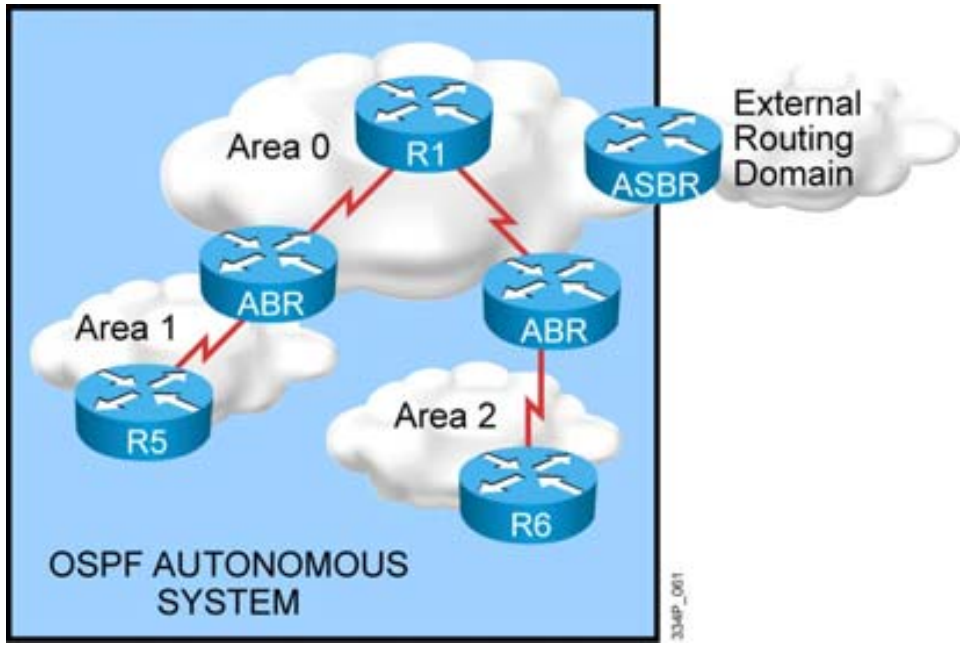
OSPF – Areas

- Link-state routing requires a hierarchical network structure
- This two-level hierarchy consists of the following:
  - Transit area (backbone or area 0)
  - Normal areas (nonbackbone areas)



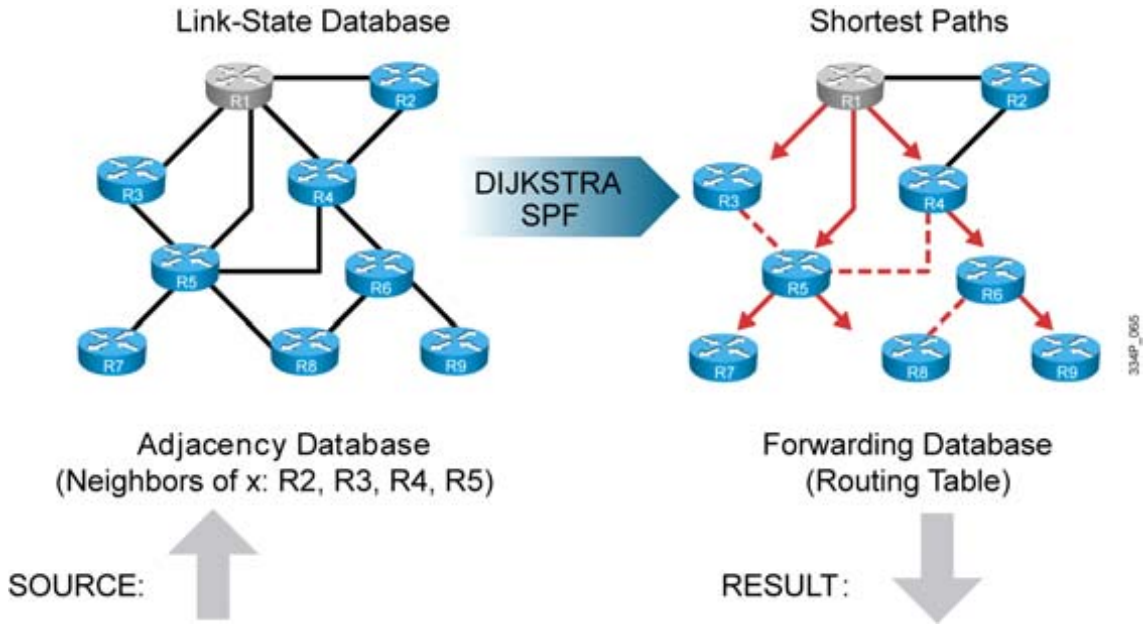
OSPF – Areas

- ABR: Area Border Router
- ASBR: Autonomous System Boundary Router
- R5, R6: Internal routers
- R1: Backbone router



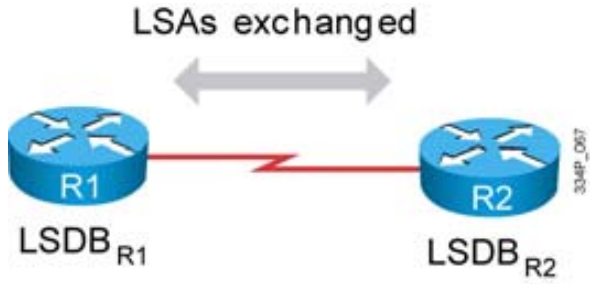
OSPF

- Routers find the best paths to destinations by applying Dijkstra's SPF algorithm to the LSDB.
- The best path is calculated based on the lowest total cost and sent to the routing table.

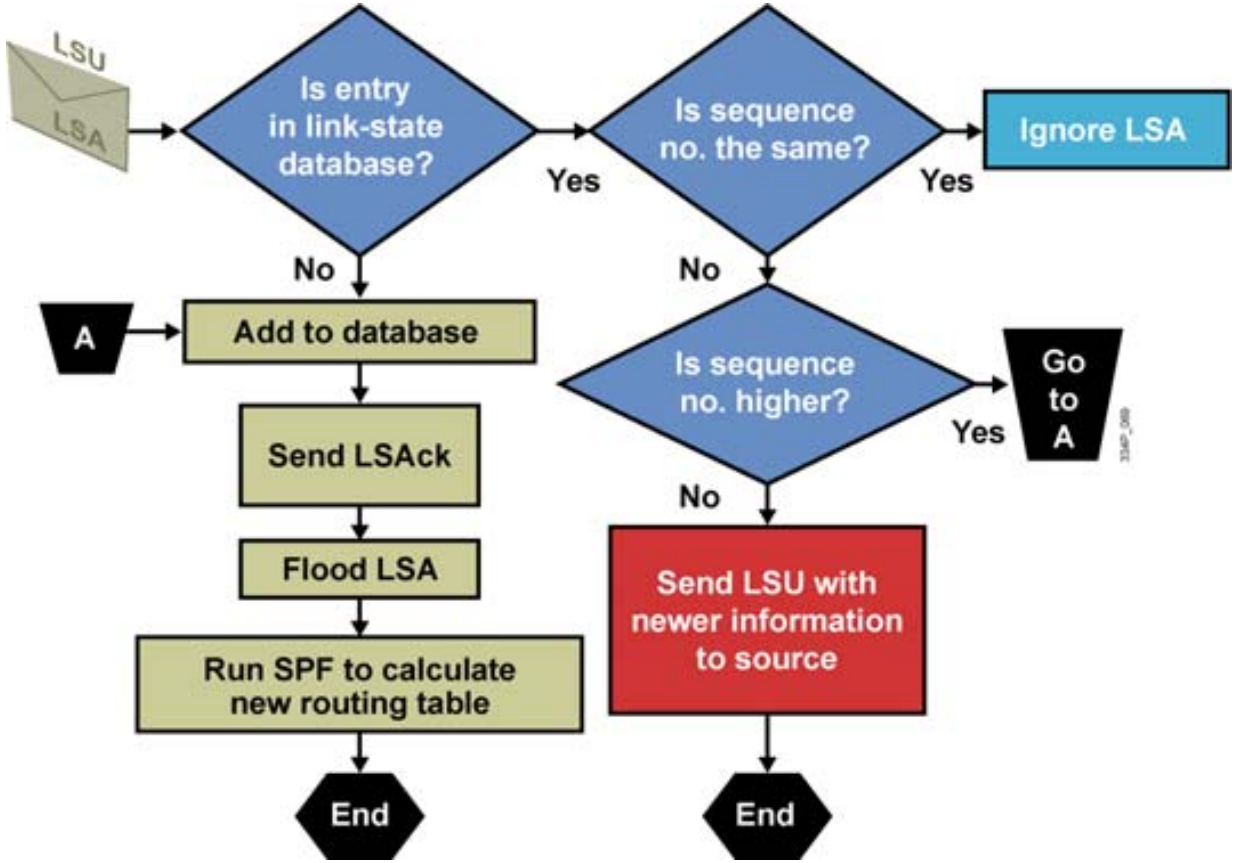


OSPF – LSDB

- The Hello protocol is used to define neighbors
- Adjacency is established
- Adjacent routers exchange LSAs
- Each router builds an LSDB using LSAs



OSPF – LSDB


LSU
LSA
Is entry in link-state database?
Yes
Is sequence no. the same?
Yes
Ignore LSA
No
No
A
Add to database
Is sequence no. higher?
Yes
Go to A
Send LSAck
No
Flood LSA
Send LSU with newer information to source
Run SPF to calculate new routing table
End
End

OSPF – LSA

- Every OSPF router announces a router LSA for those interfaces that it owns in that area.
- Router with link ID 192.168.1.67 has been updated eight times; the last update was 48 seconds ago.

```
R1#show ip ospf database

            OSPF Router with ID (192.168.1.67) (Process ID 10)
                Router Link States (Area 1)
Link ID         ADV Router      Age  Seq#       Checksum  Link count
192.168.1.67    192.168.1.67    48   0x80000008 0xB112    2
192.168.2.130   192.168.2.130   212  0x80000006 0x3F44    2
<output omitted>
```

OSPF - Functions

High-level functions of OSPF include the following:

- Discover neighbors and form adjacencies
- Flood link-state database (LSDB) information
- Compute the shortest path
- Install routes in the route-forwarding table

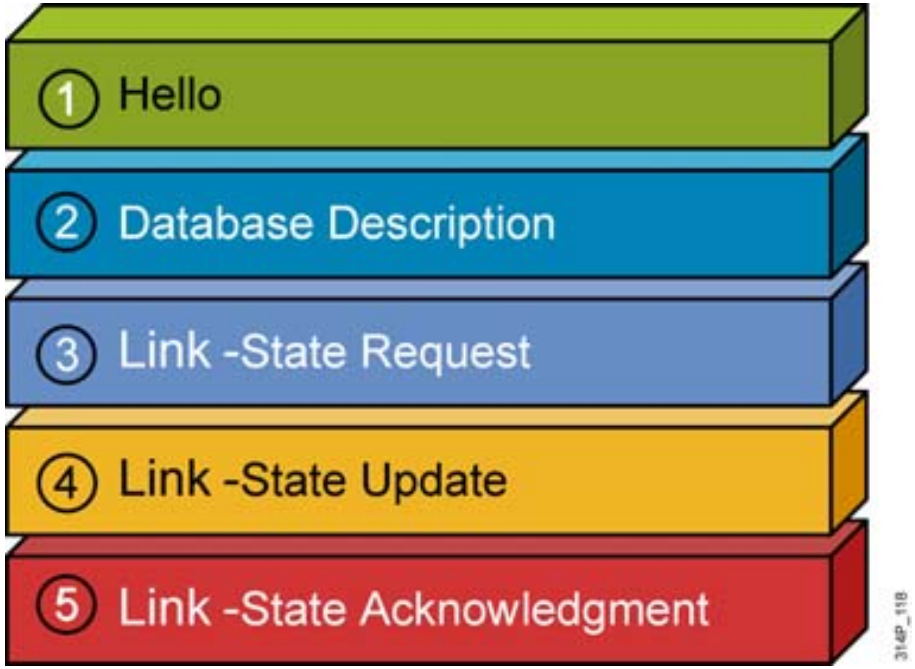
Additional functions of OSPF include the following:

- Detect changes in the link state
- Propagate changes to maintain link-state database synchronization

Several OSPF packet types are involved

OSPF - Packets

- OSPF uses five types of routing protocol packets.



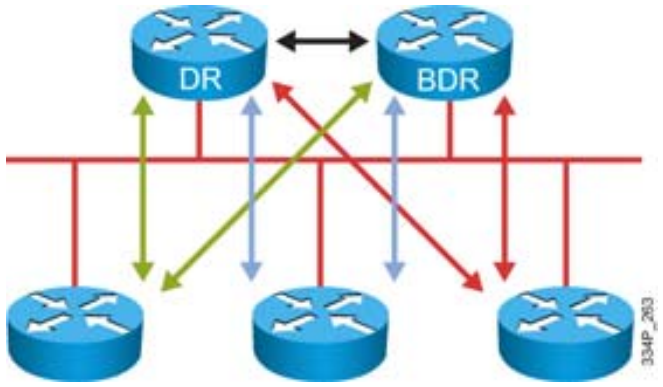
OSPF Point-to-Point

- Usually a serial interface running either PPP or HDLC

- Does not require DR or BDR election
- Is automatically detected by OSPF
- Sends OSPF packets using multicast 224.0.0.5

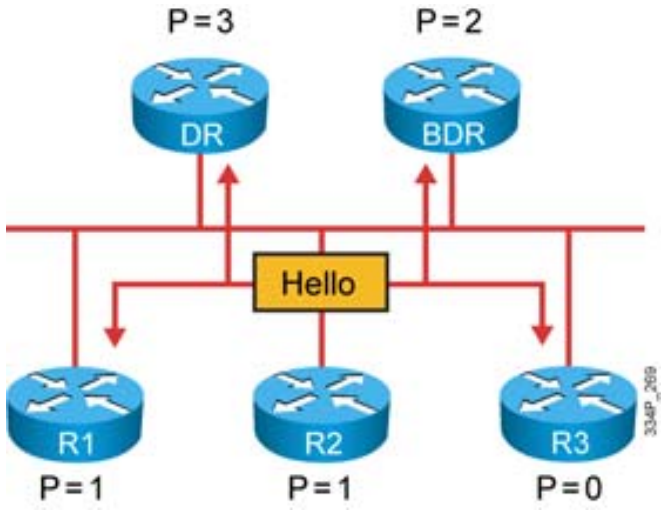
OSPF Multi-access Broadcast Network

- This generally applies to LAN technologies like Ethernet.
- DR and BDR selection are required.
- All neighbor routers form full adjacencies with the DR and BDR only.
- Packets to the DR and the BDR use 224.0.0.6.
- Packets from DR to all other routers use 224.0.0.5.



Electing the DR and the BDR

- Hello packets are exchanged via IP multicast
- DR: The router with the highest OSPF priority
- BDR: The router with the second-highest priority value
- The OSPF router ID is used as the tiebreaker
- The DR election is nonpreemptive



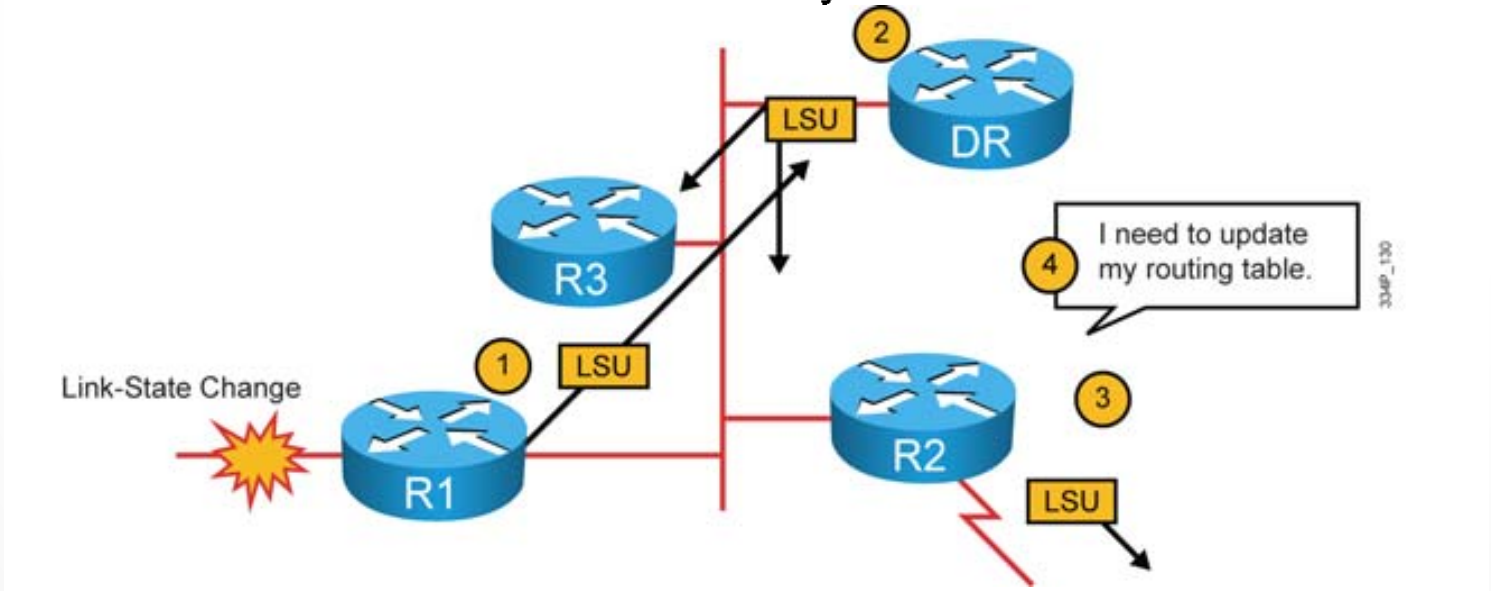
Electing the DR and the BDR

```
DR(config-if)#
ip ospf priority 3
```

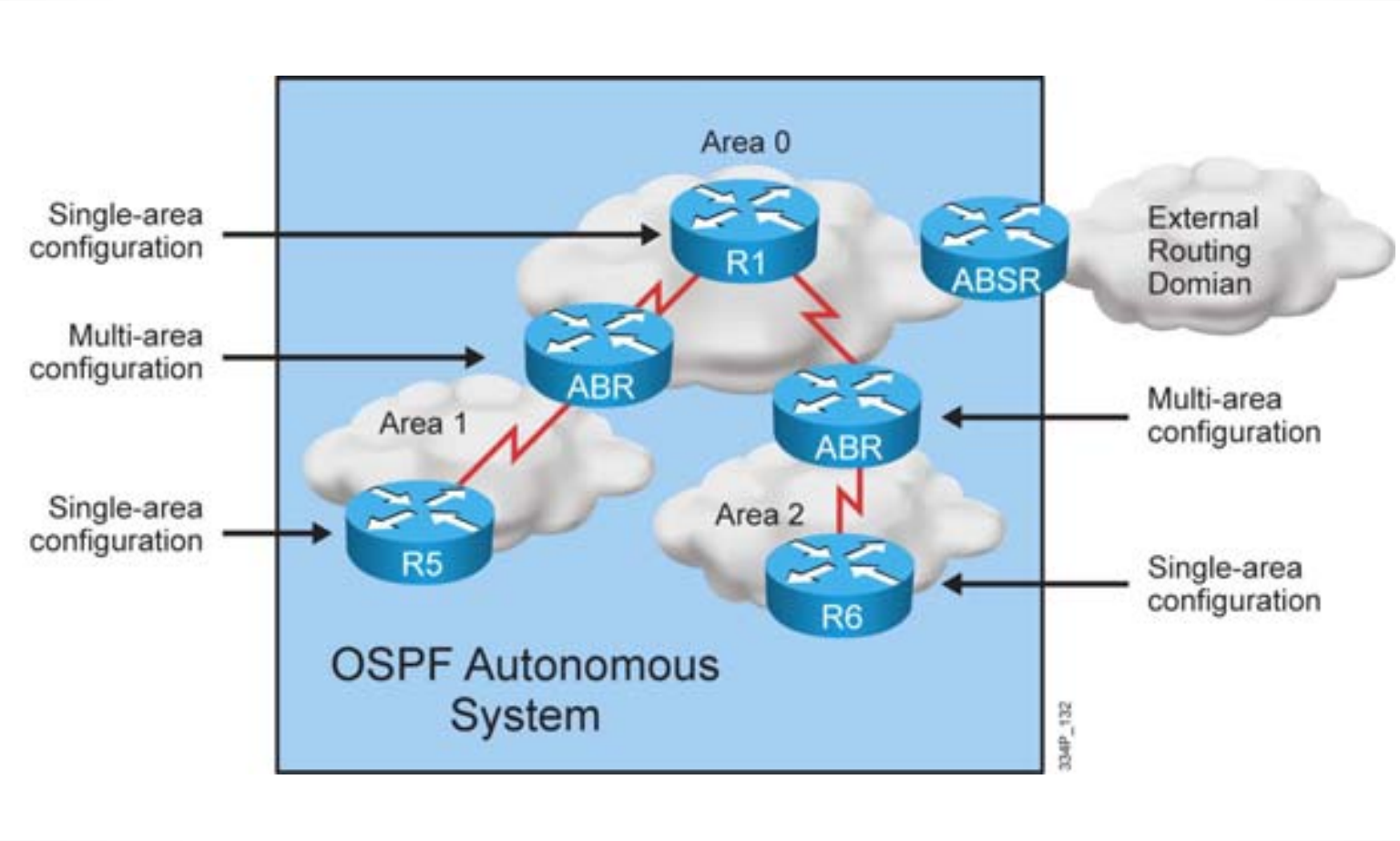
- This interface configuration command assigns the OSPF priority to an interface.
- Different interfaces on a router may be assigned different values.
- The default priority is 1. The range is from 0 to 255.
- “0” means the router cannot be the DR or BDR.
- A router that is not the DR or BDR is DROTHER.

OSPF – Topology changes

- A router that detects a topology change adjusts its LSA and floods the LSA
- Router R1 notifies all OSPF neighbors or all OSPF DRs and BDRs on LAN link using 224.0.0.6.
- The DR notifies others on 224.0.0.5.
- The LSDBs of all routers must be synchronized.



OSPF - Configuration



OSPF - Planning

- Assess the requirements and options:
  - Contiguous IP addressing plan
  - Network topology with multiple areas
- Define different area types, ABRs, and ASBRs
- Define summarization and redistribution points
- Create an implementation plan

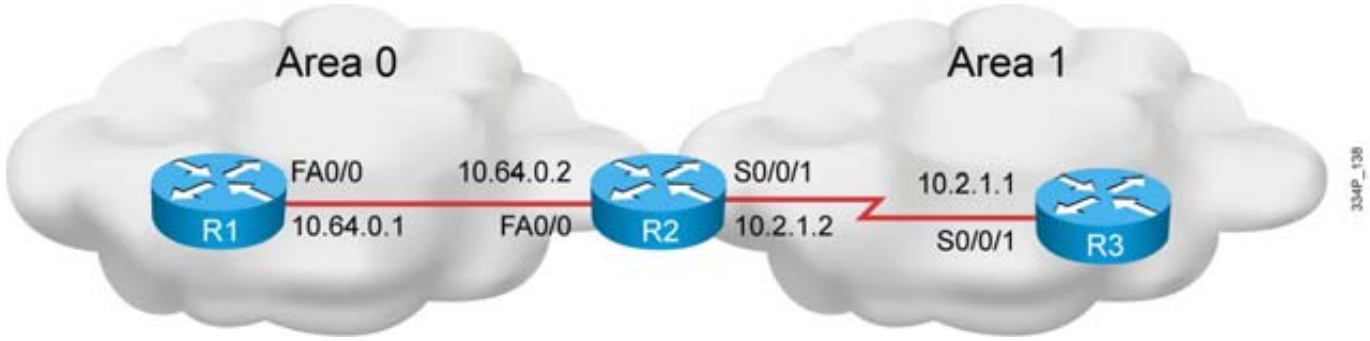
OSPF – Basic configuration

- Configure OSPF routing processes on every OSPF router
  - Define one or more processes globally on the router
  - Define the interfaces that OSPF will run on

Or

- Enable OSPF explicitly on an interface

OSPF – Multiple Areas



R1#

```
<output cmitted>
interface Fast Ethernet0/0
  ip address 10.64.0.1  255.255.255.0

<output cmitted>
router ospf 1
 network 10.0.0.0  0.255.255.255 area 0
```

R2#

```
<output omitted>
interface Fast Ethernet0/0
  ip address 10.64.0.2  255.255.255.0

interface Serial 0/0/1
  ip address 10.2.1.2  255.255.255.0
  ip ospf 50 area 1

<output omitted>
router ospf 50
 network 10.64.0.2  0.0.0.0 area 0
```

OSPF – Router ID

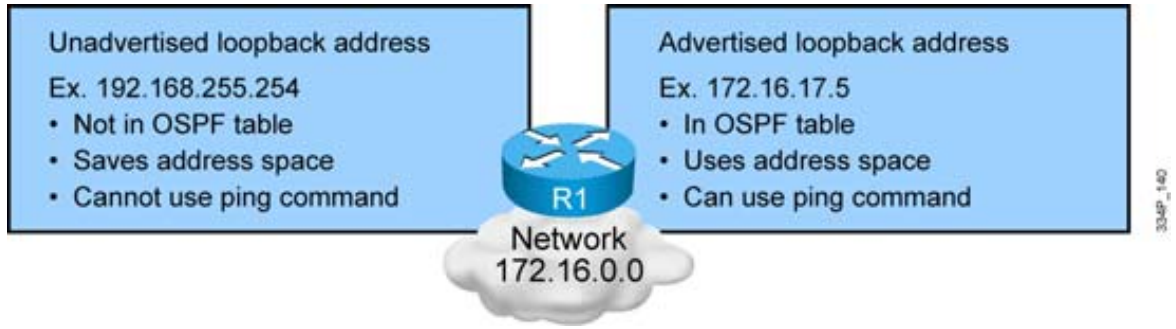
- The router is known to OSPF by the router ID number.
- This router ID is used in LSDBs to differentiate one router from the next.
- OSPF requires at least one active interface with an IP address.
- By default, the router ID is:
  - The highest IP address on an active interface at the moment of OSPF process startup.
  - If a loopback interface exists, the router ID is the highest IP address on any active loopback interface. A loopback interface overrides the OSPF router ID.
- The OSPF **router-id** command can be used to override the default OSPF router ID selection process.
- Using a loopback interface or a **router-id** command is recommended for stability.

OSPF – Loopback Interfaces

```
R1(config)#
interface loopback 0
 ip address 172.16.17.5 255.255.255.255
```

OSPF is running and the new loopback takes effect in either of these two situations:

- When the router is reloaded
- When the OSPF process is removed and reconfigured



OSPF – Setting OSPF router ID

```
R1(config-router)#
router-id  10.10.10.1
```

- This OSPF routing process configuration command changes the OSPF router ID.
- The 32-bit number in the IP address format is used.
- This must be configured before the OSPF process, otherwise the OSPF process needs to be restarted or the router must be reloaded.

```
R1#
clear ip ospf process
```

- This is the command for a manual OSPF process restart.

OSPF – Router ID Verification

```
R2#show ip ospf
 Routing Process "ospf 50" with ID 10.64.0.2
<output omitted>

 Number of areas in this router is 2. 2 normal 0 stub 0 nssa
 Number of areas transit capable is 0
 External flood list length 0
 IETF NSF helper support enabled
 Cisco NSF helper support enabled
    Area BACKBONE(0)
        Number of interfaces in this area is 1
        Area has no authentication
        SPF algorithm last executed 00:01:17.896 ago
        SPF algorithm executed 4 times
<output omitted>
  Area 1
        Number of interfaces in this area is 1
        Area has no authentication
        SPF algorithm last executed 00:00:46.668 ago
        SPF algorithm executed 3 times
<output omitted>
```

OSPF – Steps to Verify Basic OSPF

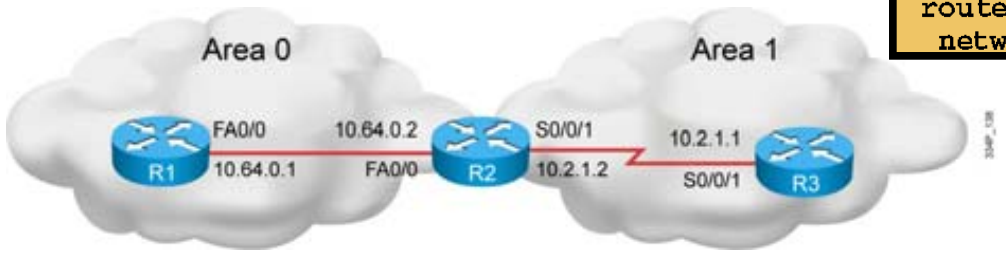
- Verify OSPF routing protocol
- Verify OSPF interface information
- Verify OSPF neighbors
- Verify OSPF routes learned by the router in the IP routing table
- Verify configured IP routing protocol processes
- Verify OSPF link state database (LSDB)

R1#

```
<output omitted>
interface Fast Ethernet0/0
  ip address 10.64.0.1  255.255.255.0

<output omitted>
router ospf 1
 network 10.0.0.0  0.255.255.255 area 0
```

R2#

```
<output omitted>
interface Fast Ethernet0/0
  ip address 10.64.0.2  255.255.255.0

interface Serial 0/0/1
  ip address 10.2.1.2  255.255.255.0
  ip ospf 50 area 1

<output omitted>
router ospf 50
 network 10.64.0.2  0.0.0.0 area 0
```



OSPF – Show ip OSPF Command

- This command displays the OSPF router ID, timers, and statistics.

```
R1#show ip ospf
Routing Process "ospf 1" with ID 10.64.0.1
 Start time: 00:01:16.084, Time elapsed: 00:14:58.368
<output omitted>
 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
 LSA group pacing timer 240 secs
 Interface flood pacing timer 33 msecs
 Retransmission pacing timer 66 msecs
 <output omitted>
 Number of areas in this router is 1. 1 normal 0 stub 0 nssa
 Number of areas transit capable is 0
 <output omitted>
   Area BACKBONE(0)
        Number of interfaces in this area is 1
        Area has no authentication
        SPF algorithm last executed 00:07:26.520 ago
        SPF algorithm executed 3 times
<output omitted>
```

OSPF – Show ip OSPF interface Command

- This command displays the OSPF router ID, area ID, and adjacency information.

```
R2#show ip ospf interface FastEthernet 0/0
FastEthernet0/0 is up, line protocol is up
  Internet Address 10.64.0.2/24, Area 0
  Process ID 50, Router ID 10.64.0.2, Network Type BROADCAST, Cost: 1
  Transmit Delay is 1 sec, State BDR, Priority 1
  Designated Router (ID) 10.64.0.1, Interface address 10.64.0.1
  Backup Designated router (ID) 10.64.0.2, Interface address 10.64.0.2
  Timer intervals configured, Hello 10, Dead 40, Wait 40, Retransmit 5
    oob-resync timeout 40
    Hello due in 00:00:05
  Supports Link-local Signaling (LLS)
  Cisco NSF helper support enabled
  IETF NSF helper support enabled
  Index 1/2, 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 0 msec
  Neighbor Count is 1, Adjacent neighbor count is 1
    Adjacent with neighbor 10.64.0.1  (Designated Router)
  Suppress hello for 0 neighbor(s)
```

OSPF – Show ip OSPF neighbor Command

- This command displays information about the OSPF neighbors, including the DR and BDR information.

```
R2#show ip ospf neighbor

Neighbor ID     Pri   State           Dead Time   Address     Interface
10.64.0.1         1   FULL/DR         00:00:32    10.64.0.1   FastEthernet0/0
10.2.1.1          0   FULL/  -        00:00:37    10.2.1.1    Serial0/0/1
```

```
R2#show ip ospf neighbor detail
  Neighbor 10.64.0.1, interface address 10.64.0.1
    In the area 0 via interface FastEthernet1/0
    Neighbor priority is 1, State is FULL, 6 state changes
    DR is 10.64.0.1 BDR is 10.64.0.2
<output omitted>
 Neighbor 10.2.1.1, interface address 10.2.1.1
    In the area 1 via interface Serial2/0
    Neighbor priority is 0, State is FULL, 6 state changes
    DR is 0.0.0.0 BDR is 0.0.0.0
<output omitted>
```

OSPF – Show ip route OSPF Command

- This command displays all OSPF routes learned by the router.

```
R1#show ip route ospf
10.0.0.0/24 is subnetted, 2 subnets
O IA     10.2.1.0 [110/65] via 10.64.0.2, 00:04:29, FastEthernet0/0
```

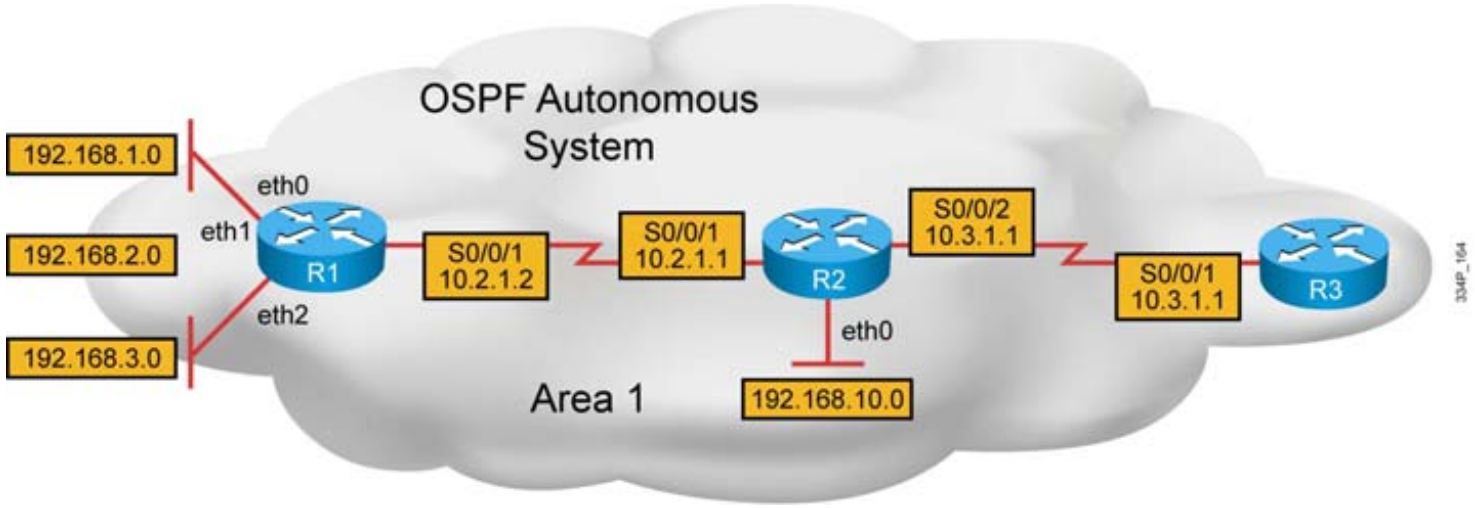
OSPF – Show ip protocols Command

- This command verifies the configured IP routing protocol processes, parameters, and statistics.

```
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 10.64.0.1
  Number of areas in this router is 1. 1 normal 0 stub 0 nssa
  Maximum path: 4
  Routing for Networks:
    10.0.0.0 0.255.255.255 area 0
 Reference bandwidth unit is 100 mbps
<output omitted>
```

OSPF – Limiting Adjacencies in OSPF

- The sending and receiving of routing updates is disabled.
- The specified interface address appears as a stub network in the OSPF domain.



R1#

```
router ospf 100
 network 192.168.0.0 0.0.255.255 area 1
 network 10.2.0.0 0.0.255.255 area 1
 passive-interface default
 no passive-interface Serial0/0/1
```

R2#

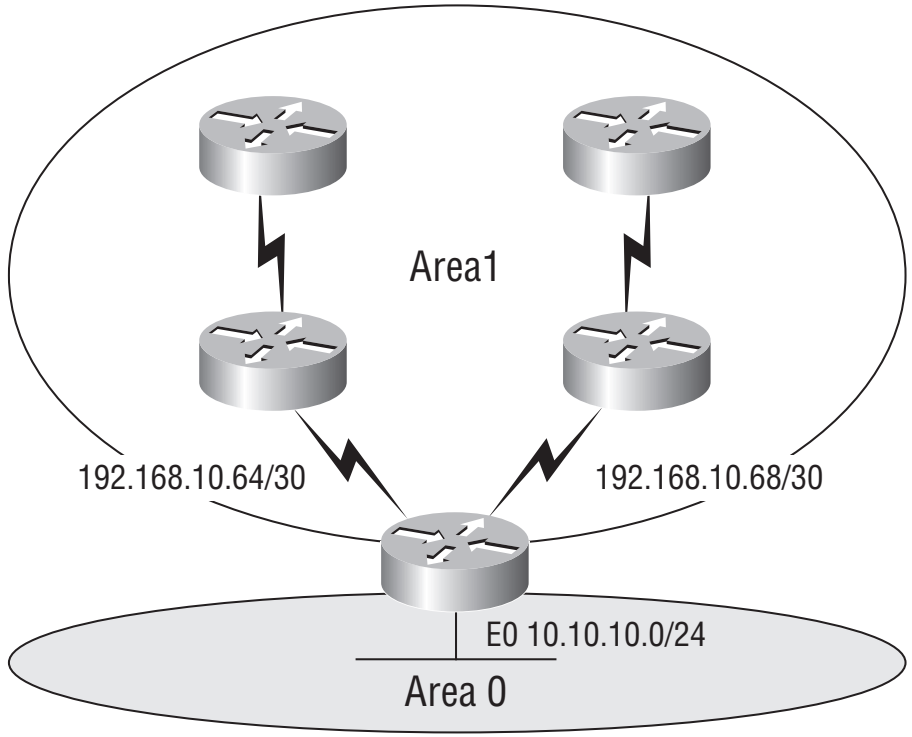
```
router ospf 100
 network 192.168.0.0 0.0.255.255 area 1
 network 10.2.0.0 0.0.255.255 area 1
 network 10.3.0.0 0.0.255.255 area 1
 passive-interface Ethernet0
```

OSPF – OSPF Cost

- The cost, or metric, is an indication of the overhead to send packets over an interface.
- OSPF cost is used as the route selection criteria.
- Dijkstra's algorithm determines the best path by adding all link costs along a path.
- OSPF cost is computed automatically.
  - Cost = 10^7 / Bandwidth
  - Bandwidth is specified on the interface with the **bandwidth** command.
- OSPF cost is recomputed after every bandwidth change.

OSPF – Route Summarization

- Minimizes the number of routing table entries
- Localizes the impact of a topology change
- Reduces LSA flooding and saves CPU resources

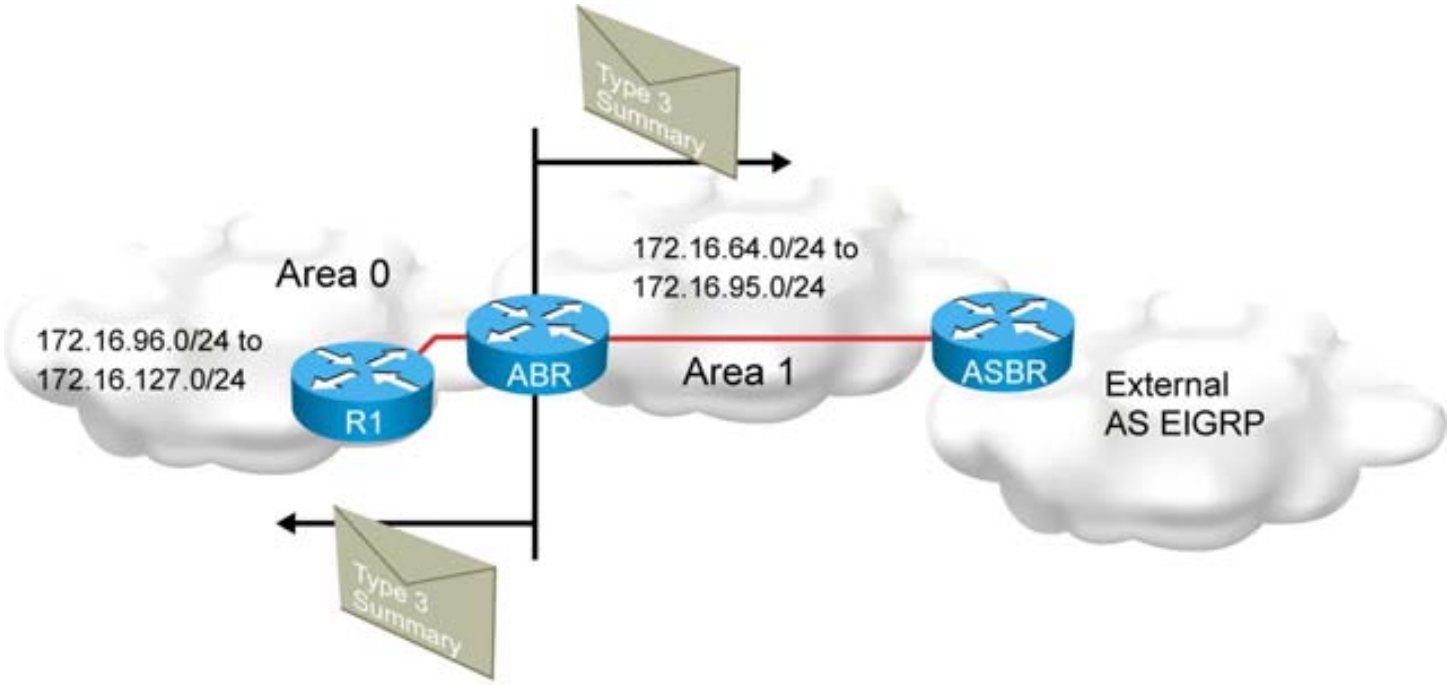


OSPF – Route Summarization

```
Core#config t
Core(config)#router ospf 1
Core(config-router)#network 192.168.10.64 0.0.0.3 area 1
Core(config-router)#network 192.168.10.68 0.0.0.3 area 1
Core(config-router)#network 10.10.10.0 0.0.0.255 area 0
Core(config-router)#area 1 range 192.168.10.64 255.255.255.224
```

The no auto-summary command is not needed since OSPF does not summarize at any boundary by default.

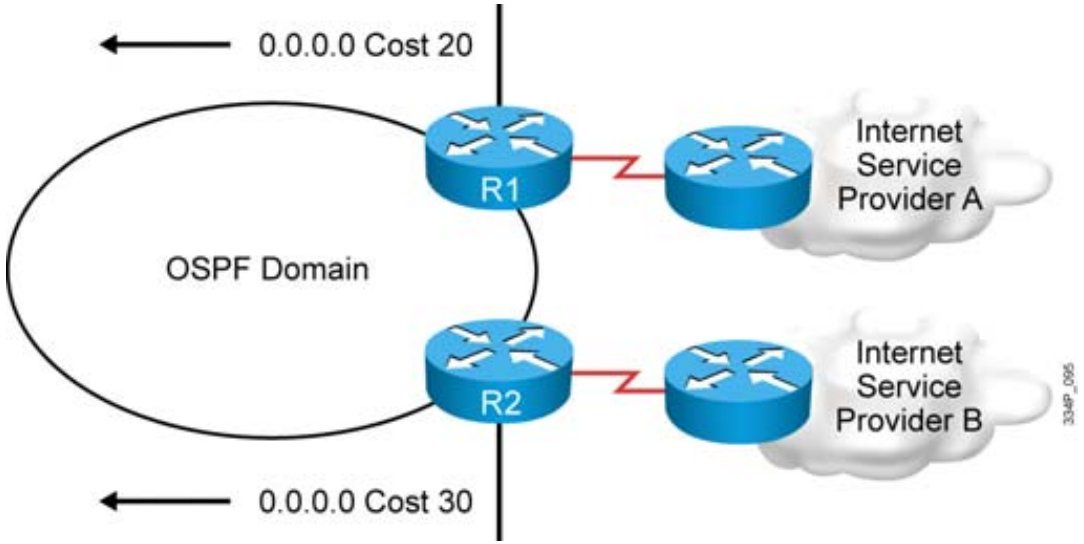
OSPF – Route Summarization



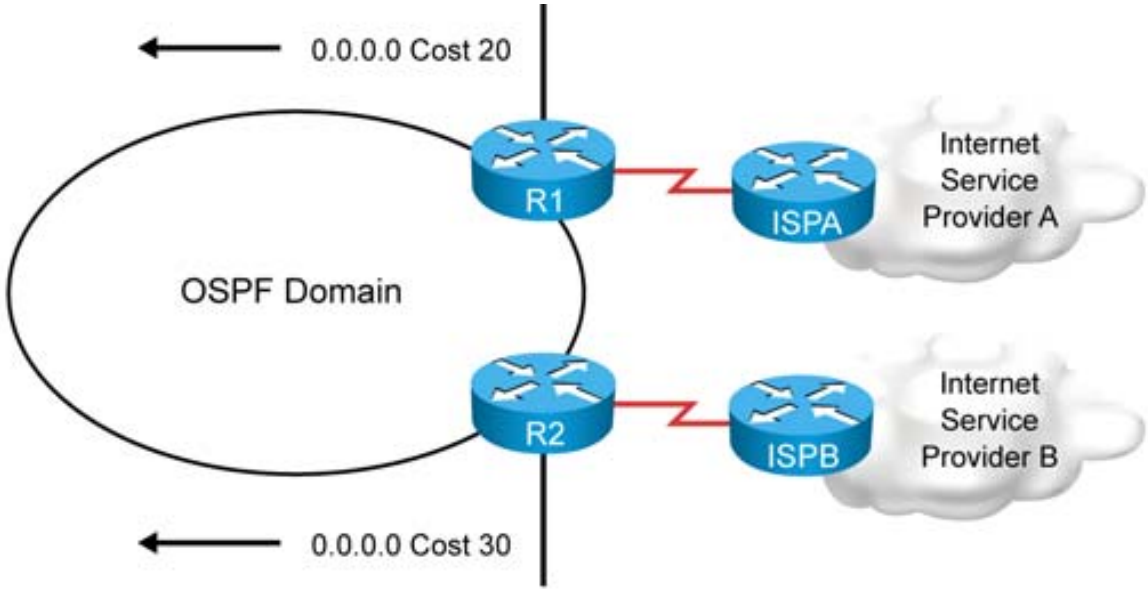

```
ABR (config) # router ospf 100
ABR (config-router) #network 172.16.64.1 0.0.0.0 area 1
ABR (config-router) #network 172.16.127.1 0.0.0.0 area 0
ABR (config-router) #area 0 range 172.16.96.0 255.255.224.0
ABR (config-router) #area 1 range 172.16.64.0 255.255.224.0
```

OSPF – Default Routes

- Default route distribution is not on by default.
- Benefits of default routes include:
  - A smaller routing table
  - Fewer resources used in the router



OSPF – Default Routes

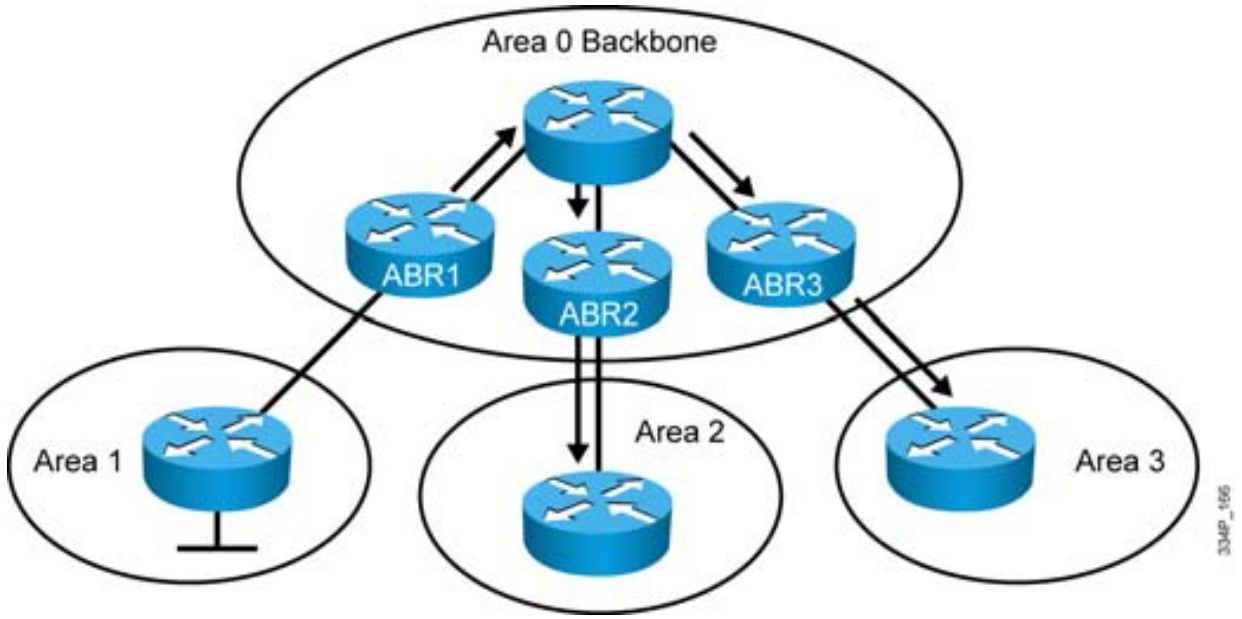



```
R1#
router ospf 100
network 10.1.1.1  0.0.0.0 area 0
default-information originate metric 10

ip route 0.0.0.0  0.0.0.0  198.1.1.2
```

```
R2#
router ospf 100
network 10.2.1.1  0.0.0.0 area 0
default-information originate metric 100

ip route 0.0.0.0  0.0.0.0  198.2.1.2
```

OSPF – Virtual Links

- If more than one area is configured, one of these areas has be to be area 0, the backbone area.
- All areas must be connected to area 0.
- Area 0 must be contiguous.



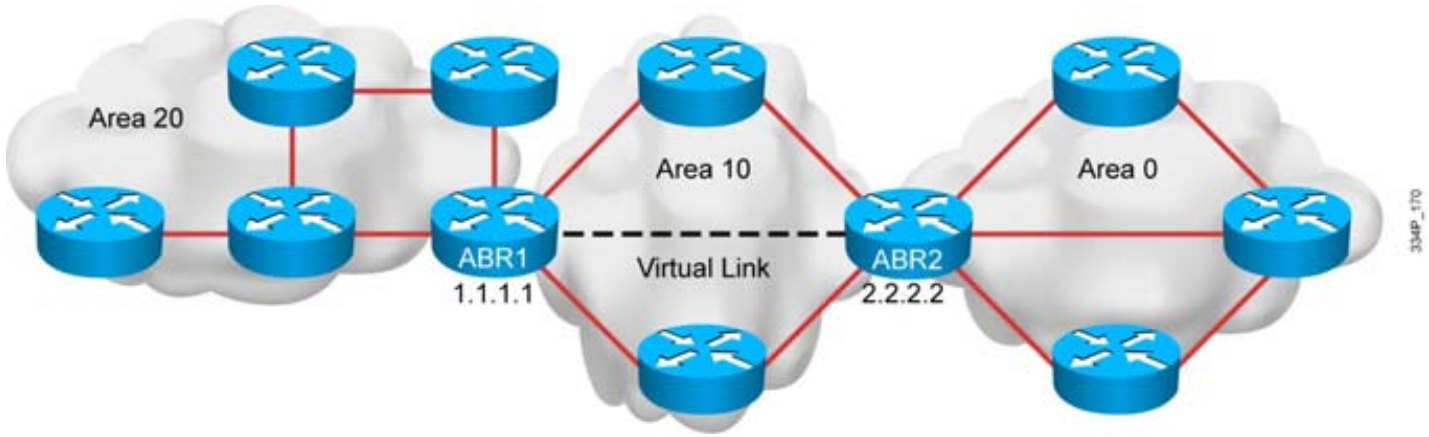
OSPF – Virtual Links as a solution

- An extension to the backbone
- Carried by a nonbackbone area

- Are used to:
  - Allow areas to connect to areas other than 0
  - Repair a discontiguous area 0 (for example, if two companies merge and have separate backbone areas)

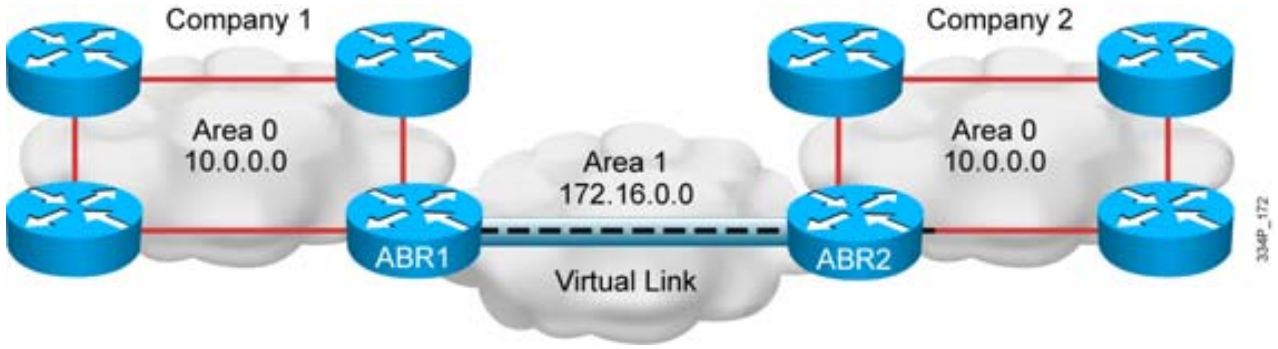
OSPF – Virtual Links

- Area 20 added with no physical access to area 0
- A virtual link provides a logical path to the backbone area
- The OSPF database treats the link between routers ABR1 and ABR2 as a direct link



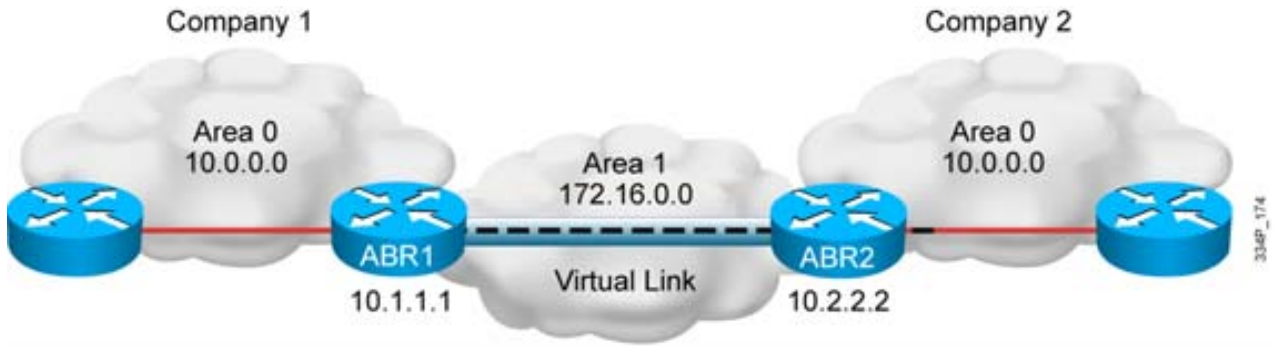
OSPF – Virtual Links

- Two companies merge without a direct link between them.
- Virtual links are used to connect the discontiguous areas 0.
- A logical link is built between routers ABR1 and ABR2.
- Virtual links are recommended for backup or temporary connections, too.



OSPF – Virtual Links Configuration

- Configure a virtual link.
- The router ID of the remote router is used in the command.



ABR1#

```
router ospf 100
 network 172.16.0.0 0.0.255.255 area 1
 network 10.0.0.0 0.255.255.255 area 0
 area 1 virtual-link 10.2.2.2
```

ABR2#

```
router ospf 100
 network 172.16.0.0 0.0.255.255 area 1
 network 10.0.0.0 0.255.255.255 area 0
 area 1 virtual-link 10.1.1.1
```

OSPF – Virtual Links Verification

```
ABR1#
```

```
show ip ospf virtual-links
```

- Verify the configuration of the virtual link.

```
ABR1#show ip ospf virtual-links

Virtual Link OSPF_VL0 to router 10.2.2.2 is up
  Run as demand circuit
  DoNotAge LSA allowed.
  Transit area 1, via interface Serial0/0/1, Cost of using 781
  Transmit Delay is 1 sec, State POINT_TO_POINT,
  Timer intervals configured, Hello 10, Dead 40, Wait 40, Retransmit 5
    Hello due in 00:00:07
    Adjacency State FULL (Hello suppressed)
    Index 1/2, retransmission queue length 0, number of retransmission 1
    First 0x0(0)/0x0(0) Next 0x0(0)/0x0(0)
    Last retransmission scan length is 1, maximum is 1
    Last retransmission scan time is 0 msec, maximum is 0 msec
```

OSPF – Virtual Links Verification

```
ABR1#
```

```
show ip ospf database
```

- Verify the virtual link in the OSPF database.

```
ABR1#show ip ospf database
      OSPF Router with ID (10.1.1.1) (Process ID 100)

                Router Link States (Area 0)

Link ID    ADV Router     Age              Seq#          Checksum    Link
count
10.1.1.1   10.1.1.1       718              0x80000002    0x189A          2
10.2.2.2   10.2.2.2       4       (DNA)    0x80000001    0x2980          1

                Summary Net Link States (Area 0)
<output omitted>
```