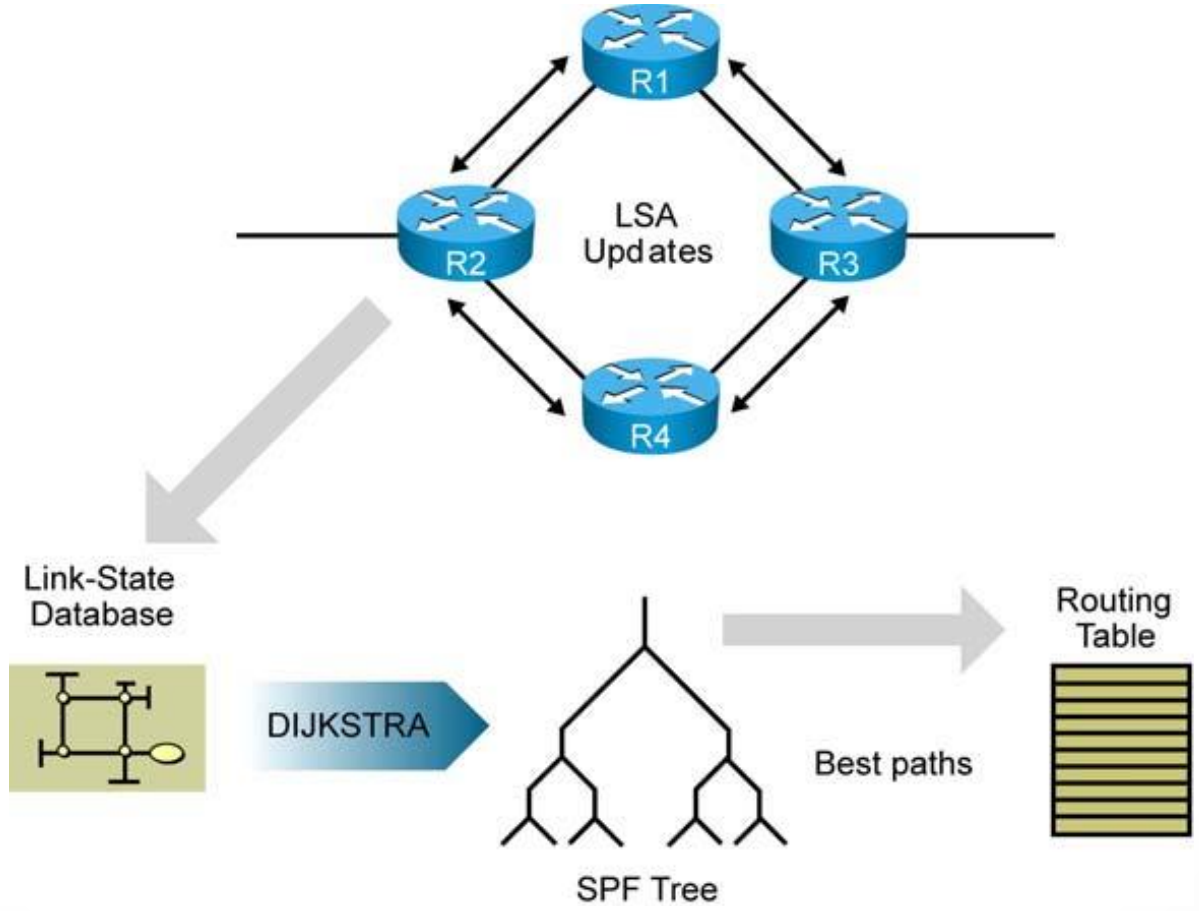
Configuration and Management of Networks

Pedro Amaral

Link State Protocols

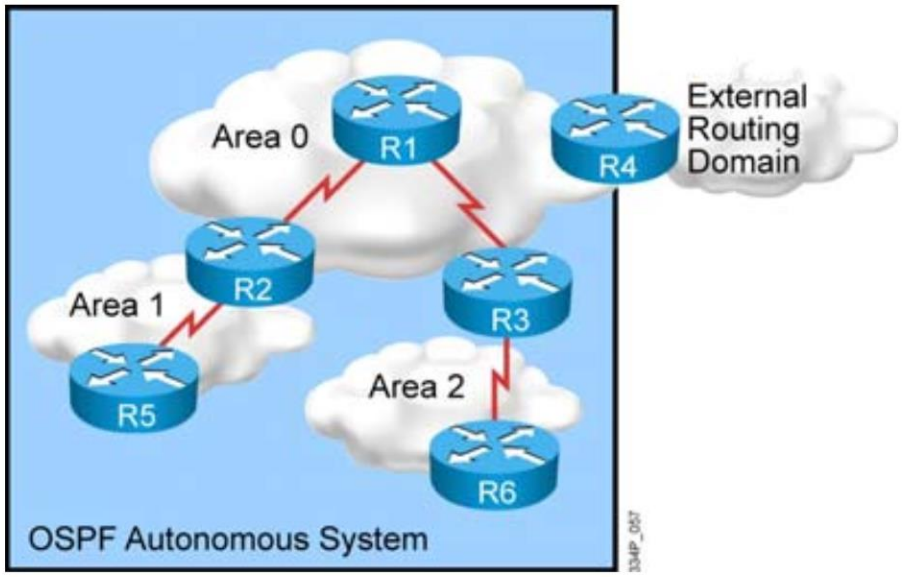


Link State Protocols

- 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

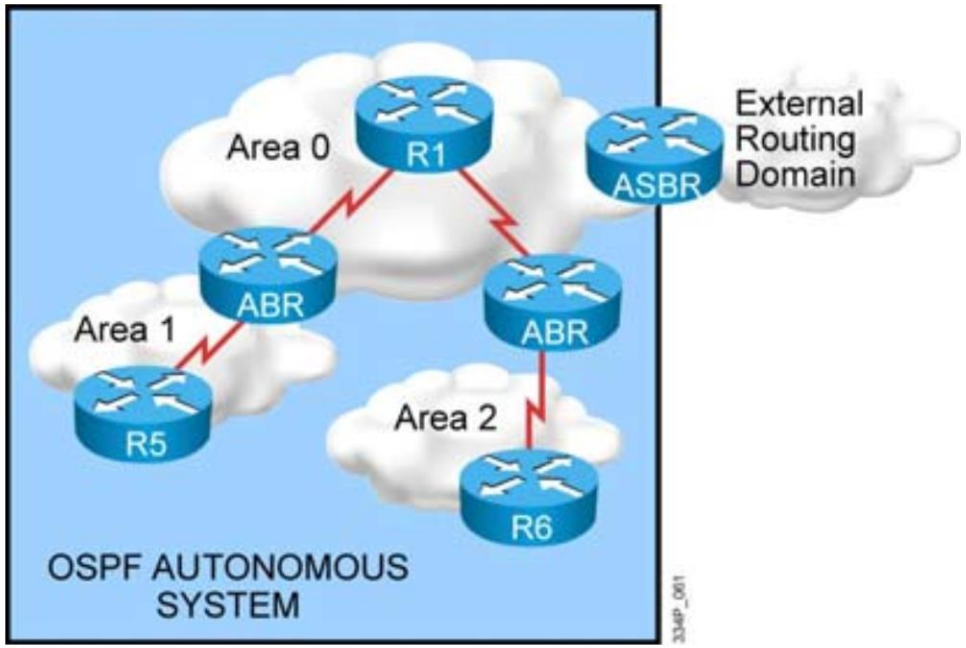
OSPF – Areas

- 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)



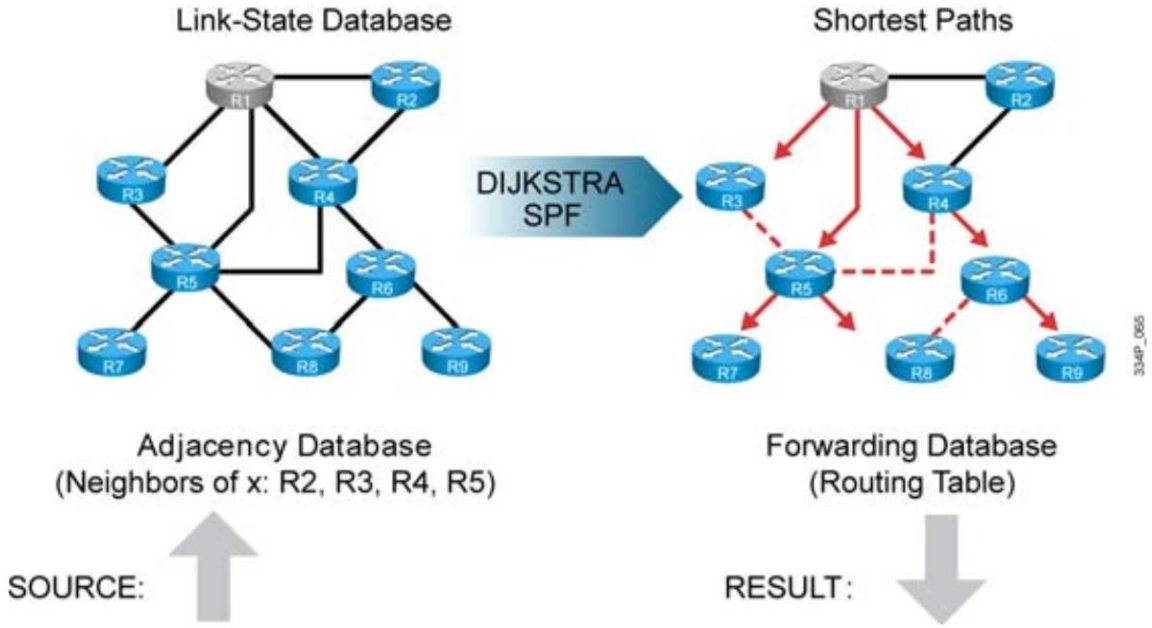
OSPF – Areas

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



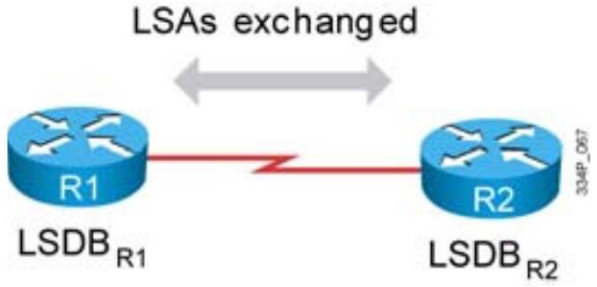
OSPF

- 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.

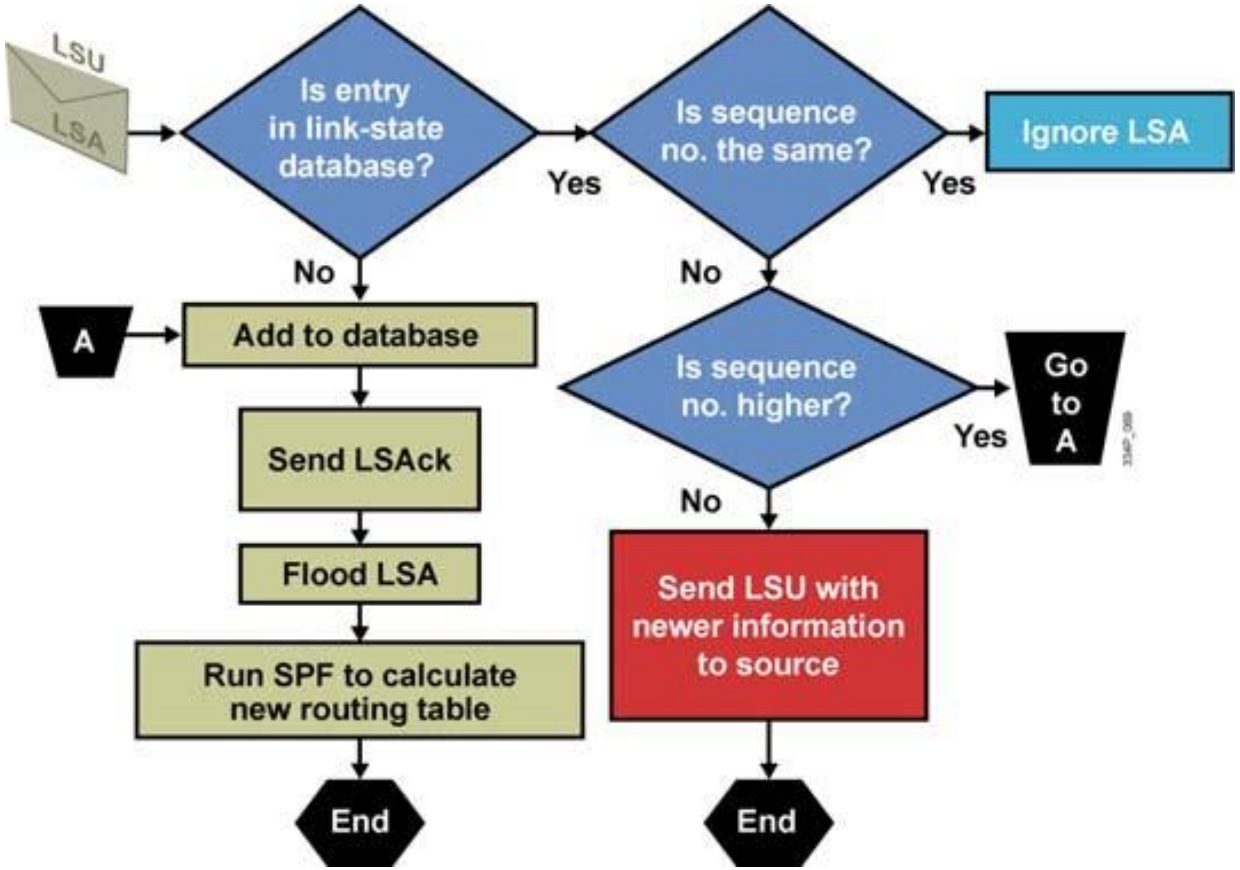


OSPF – LSDB

- 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 - 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.

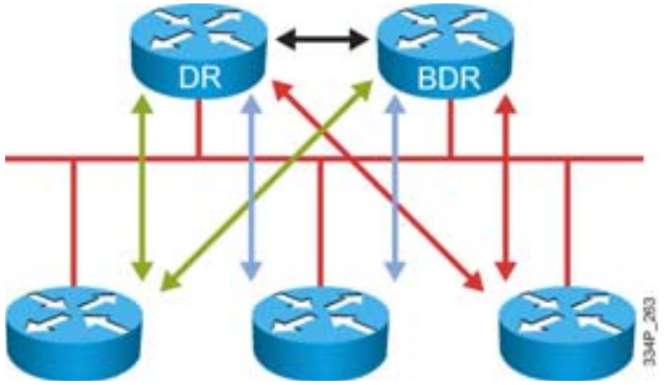
OSPF Point-to-Point

- 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.



OSPF Multi-access Broadcast Network

To configure an interface with a higher OSPF priority to ensure it becomes the Designated Router (DR) on a broadcast segment, use:

```
# Set priority to 255 (highest value wins DR election)
nv set interface swp1 router ospf priority 255
nv config apply
```

The default OSPF priority is 1. Priority ranges from 0 to 255

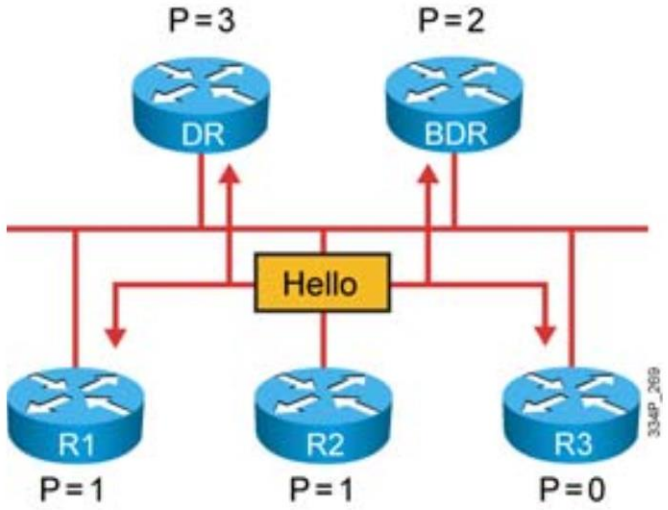
On Cumulus Linux, the default OSPF network type for swp interfaces **is point-to-point**

On a segment that is broadcas you can change the mode using the commands:

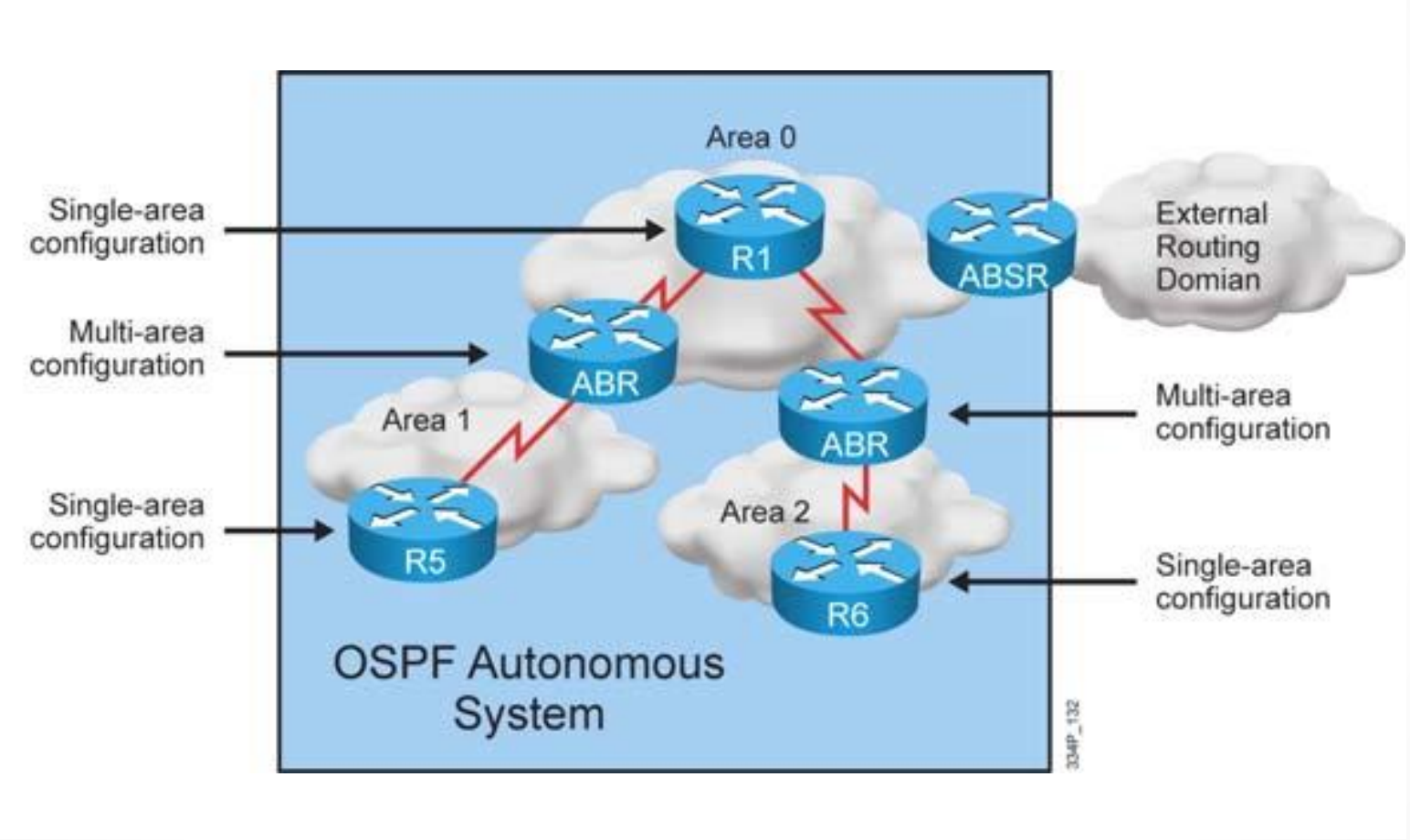
```
nv set interface swp1 ip address 10.1.10.1/24
nv set interface swp1 router ospf area 0
nv set interface swp1 router ospf network-type broadcast
nv config apply
```

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



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

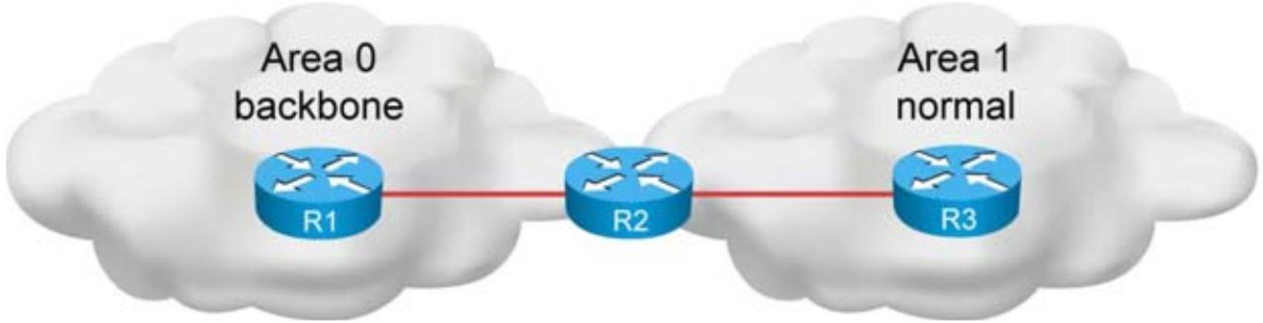
OSPF – Basic configuration

- 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

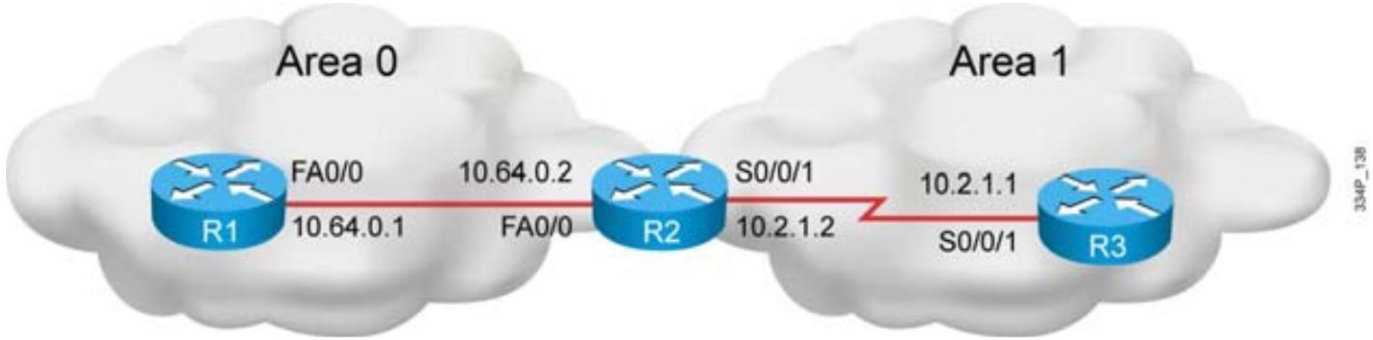
Or

- Enable OSPF explicitly on an interface

In Cumulus linux (NVDUE) it is always defined in the interfaces.



OSPF – Multiple Areas



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
```

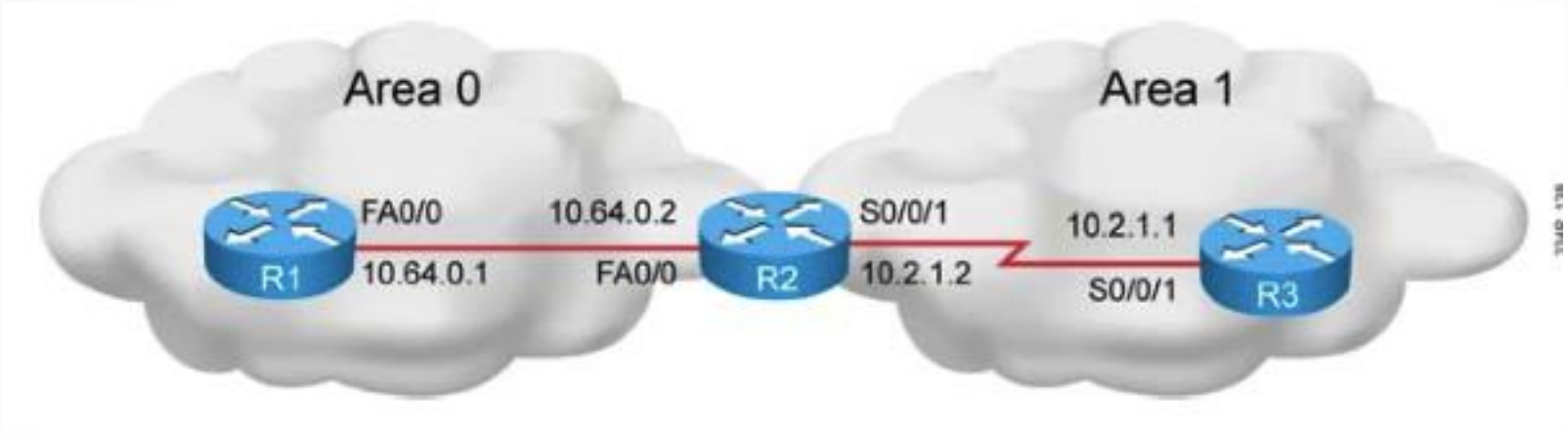
R2#

```
<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 – Multiple Areas



R1:
sudo nv set vrf default router ospf enable on

sudo nv set interface swp2 ip address 10.64.0.1/24
sudo nv set interfsace swp2 router ospf enable area 0

R2:
sudo nv set vrf default router ospf enable on

sudo nv set interface swp2 ip address 10.64.0.2/24
sudo nv set interfsace swp2 router ospf enable area 0

sudo nv set interface swp3 ip address 10.2.1.2/24
sudo nv set interfsace swp3 router ospf enable area 1

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

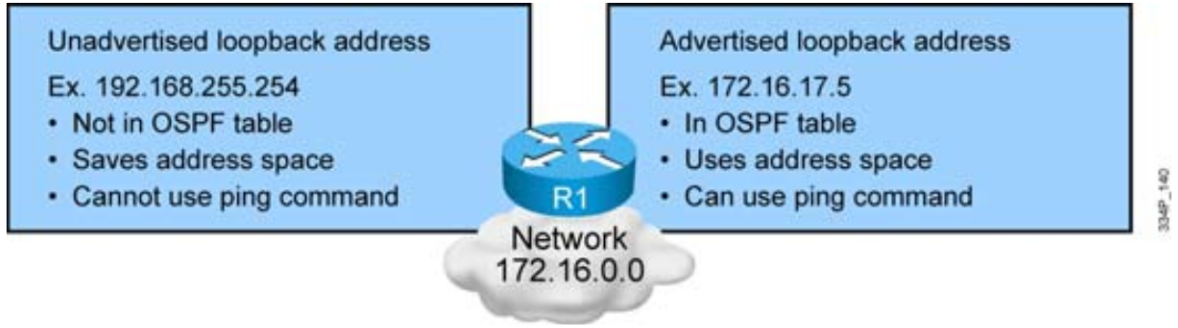
```
R1(config)#
interface loopback 0
 ip address 172.16.17.5 255.255.255.255
```

nv set interface lo ip address 172.16.17.5/32

Cumulus linus only has one looback interface but you can associate several IPs to it.

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
```

nv set vrf default router ospf 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
```

nv action clear vrf default router ospf process

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

OSPF – Router ID Verification

```
nv show vrf default router ospf
```

- This command displays OSPF router id, , timers and statistics

```
cumulus@switch:~$ nv show vrf default router ospf
                    applied
------------------- ----------
enable              on
reference-bandwidth 100000
rfc1583-compatible  off
router-id           10.10.10.1
default-originate
  enable            off
distance
....
```

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 IP table
- Verify configured IP routing protocol processes
- Verify OSPF link state database (LSDB)

OSPF – verification

```
cumulus@switch:~$ nv show vrf default router ospf interface
```

```
Interface    Summary
---------    -------------------
lo           local-ip: 10.10.10.1
swp51        local-ip: 10.0.1.0
swp52        local-ip: 10.0.2.0
vlan10       local-ip: 10.1.10.2
vlan20       local-ip: 10.1.20.2
dummy0       local-ip: 192.168.1.1
```

OSPF – verification

```
nv show vrf default router ospf interface swp51 -o json
```


```
{
  "local-ip": {
    "10.10.10.1": {
      "area-id": "0.0.0.0",
      "cost": 100,
      "counters": {
        "adjacent-neighbor-count": 1,
        "hello-tx": 98,
        "neighbor-count": 1
      },
      "dead-interval": 60,
      "hello-interval": 5000,
      "passive": "off",
      "priority": 1,
      "state": "Point-To-Point"
    }
  }
}
```

OSPF – verification

```
nv show vrf default router ospf neighbor
```

Interface	Neighbor-ID	State	Priority	DR-Address	BDR-Address	Uptime
swp51	10.10.10.2	Full	1	10.0.1.2	10.0.1.1	00:15:30
swp52	10.10.10.3	Full	1	10.0.2.3	10.0.2.1	00:12:45
vlan10	10.10.10.4	Full	128	10.1.10.4	10.1.10.2	00:20:15
vlan10	10.10.10.5	2-Way	1	10.1.10.4	10.1.10.2	00:20:10

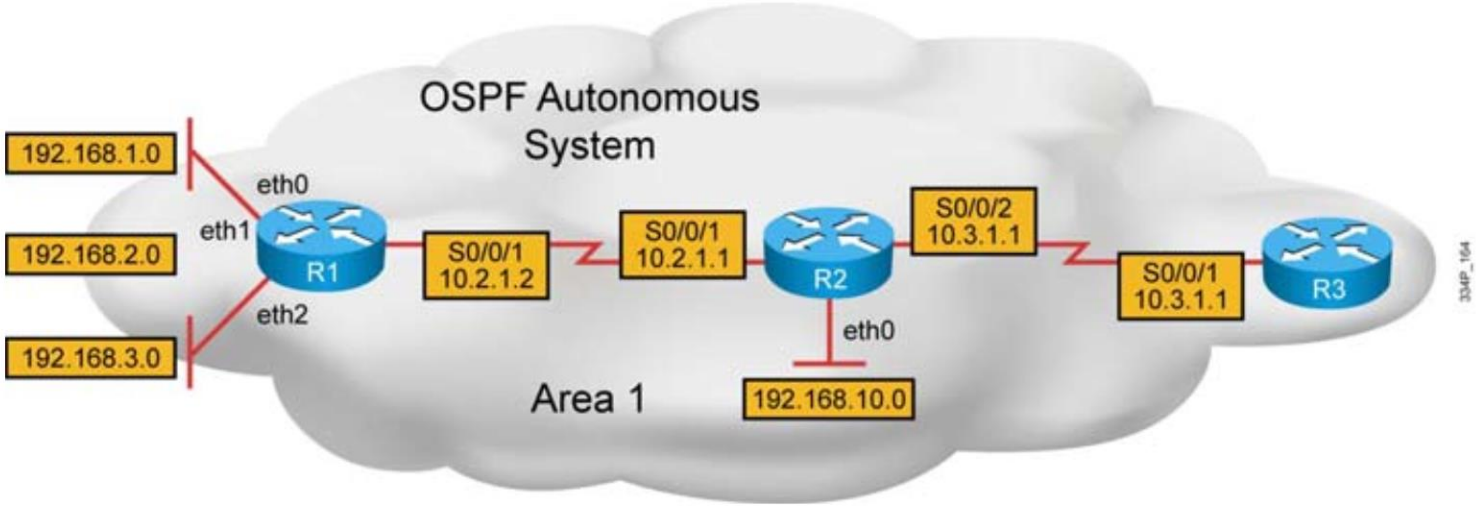
OSPF – verification

```
nv show vrf default router rib ospf
```

Address-family	Route	Route-type	Installed	Uptime	Nexthop-group-id	Via	Protocol	Metric
ipv4	10.10.10.2/32	ospf	yes	00:15:30	10	10.0.1.2	ospf	100
ipv4	10.10.10.3/32	ospf	yes	00:12:45	11	10.0.2.3	ospf	100
ipv4	192.168.1.0/24	ospf-ia	yes	00:10:20	12	10.0.1.2	ospf	110
ipv4	192.168.2.0/24	ospf-ia	yes	00:10:15	13	10.0.2.3	ospf	110
ipv4	172.16.0.0/24	ospf-e2	yes	00:05:30	14	10.0.1.2	ospf	120

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#

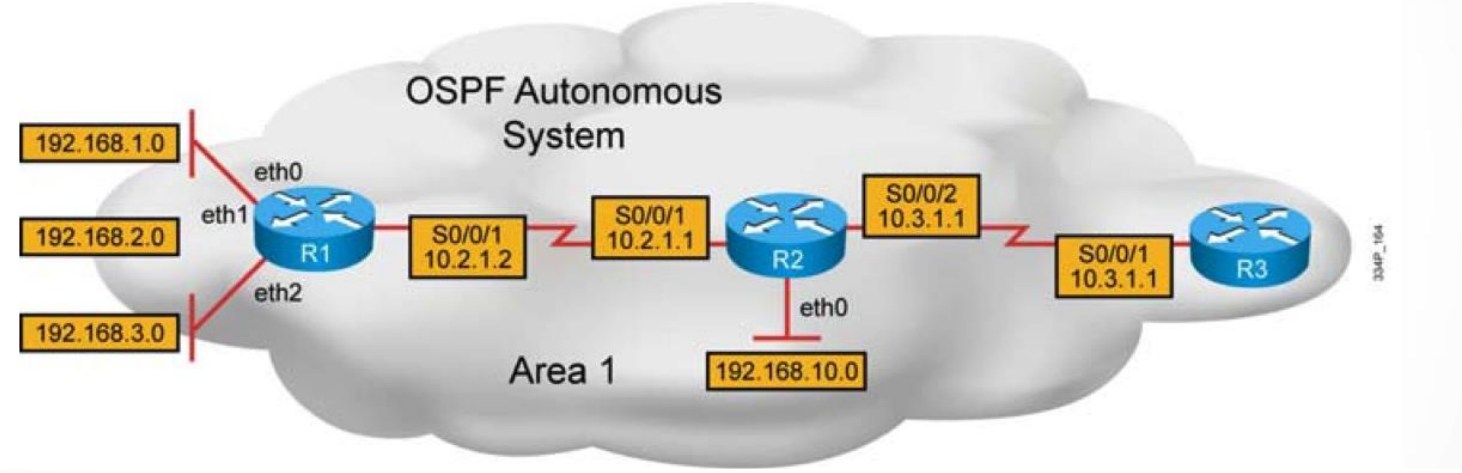
```
router ospf 100
 network 192.168.0.0 0.0.255.255 area 1
 network 10.2.0.0 0.0.255.255 area 1
 passive-interface default
 no passive-interface Serial0/0/1
```

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 – 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

```
nv set vrf default router ospf passive-interface default on
nv set interface swp1 router ospf passive off
nv config apply
```

R2

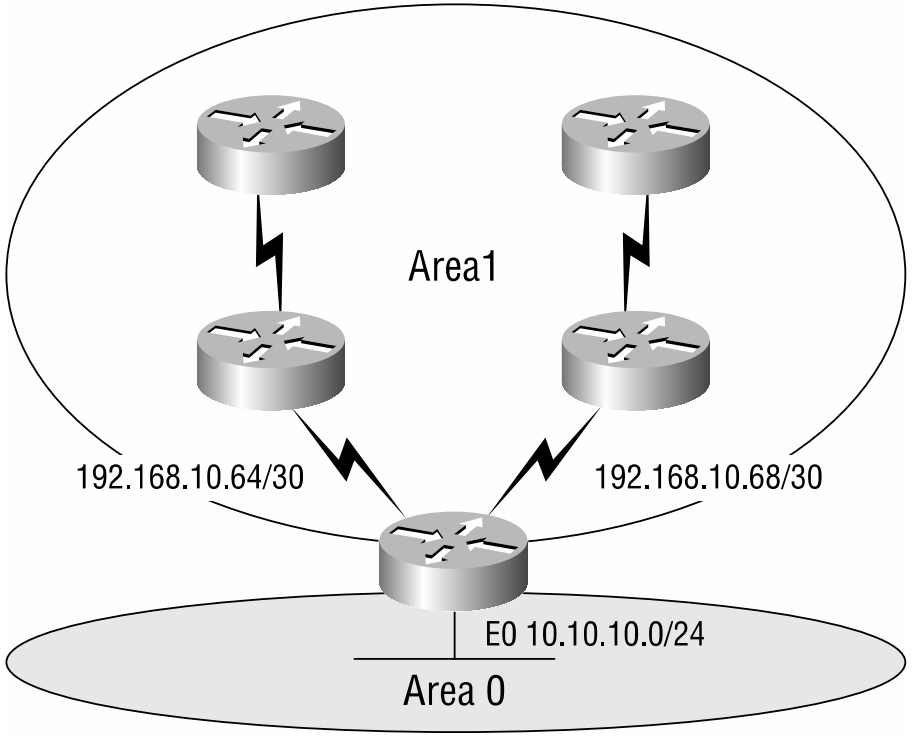
```
nv set interface swp0 router ospf passive on
nv config apply
```

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

Enable OSPF
nv set vrf default router ospf enable on
nv set vrf default router ospf router-id 10.10.10.1

Configure interfaces in their respective areas
nv set interface swp1 ip address 192.168.10.65/30
nv set interface swp1 router ospf area 1

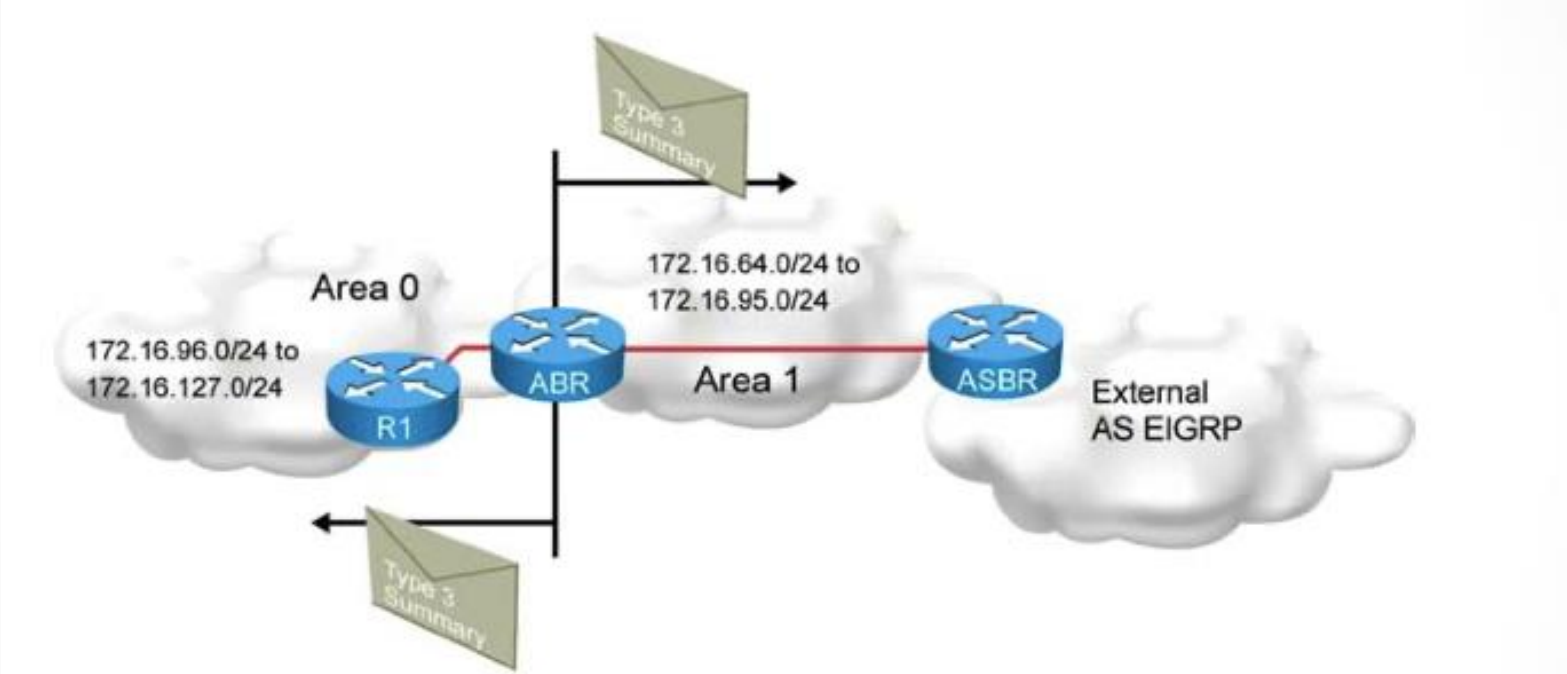
nv set interface swp2 ip address 192.168.10.69/30
nv set interface swp2 router ospf area 1

nv set interface lo ip address 10.10.10.1/32
nv set interface lo router ospf area 0

Configure area 1 route summarization
nv set vrf default router ospf area 1 range 192.168.10.64/27

Apply configuration
nv config apply

OSPF – Route Summarization

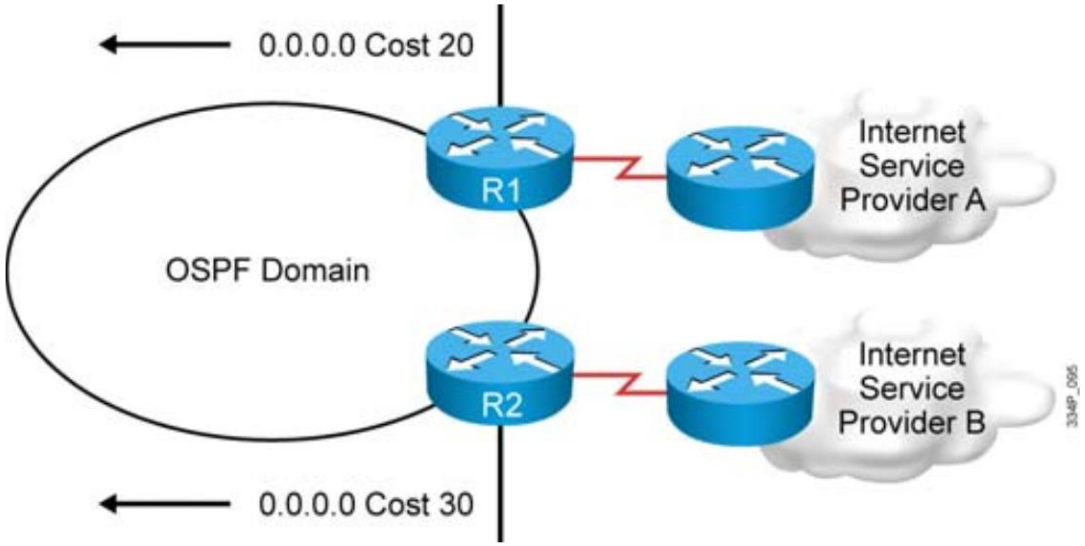



```
ABR(config)# router ospf 100
 ABR(config-router)# network 172.16.64.1 0.0.0.0 area 1
 ABR(config-router)# network 172.16.127.1 0.0.0.0 area 0
 ABR(config-router)# area 0 range 172.16.96.0 255.255.224.0
ABR(config-router)# area 1 range 172.16.64.0 255.255.224.0
```

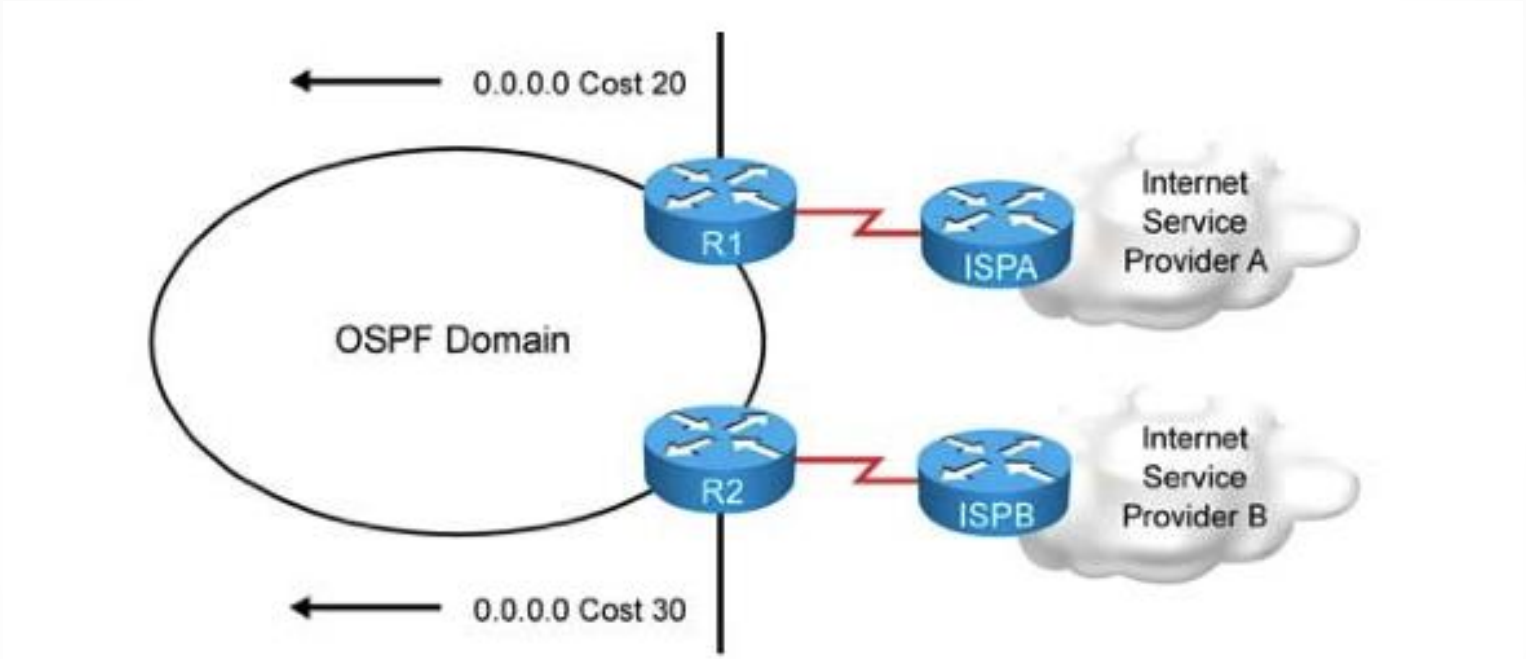
```
nv set vrf default router ospf enable on
nv set interface swp1 ip address 172.16.64.1/24
nv set interface swp1 router ospf area 1
nv set interface swp2 ip address 172.16.127.1/24
nv set interface swp2 router ospf area 0
nv set vrf default router ospf area 0 range 172.16.96.0/19
nv set vrf default router ospf area 1 range 172.16.64.0/19
```

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



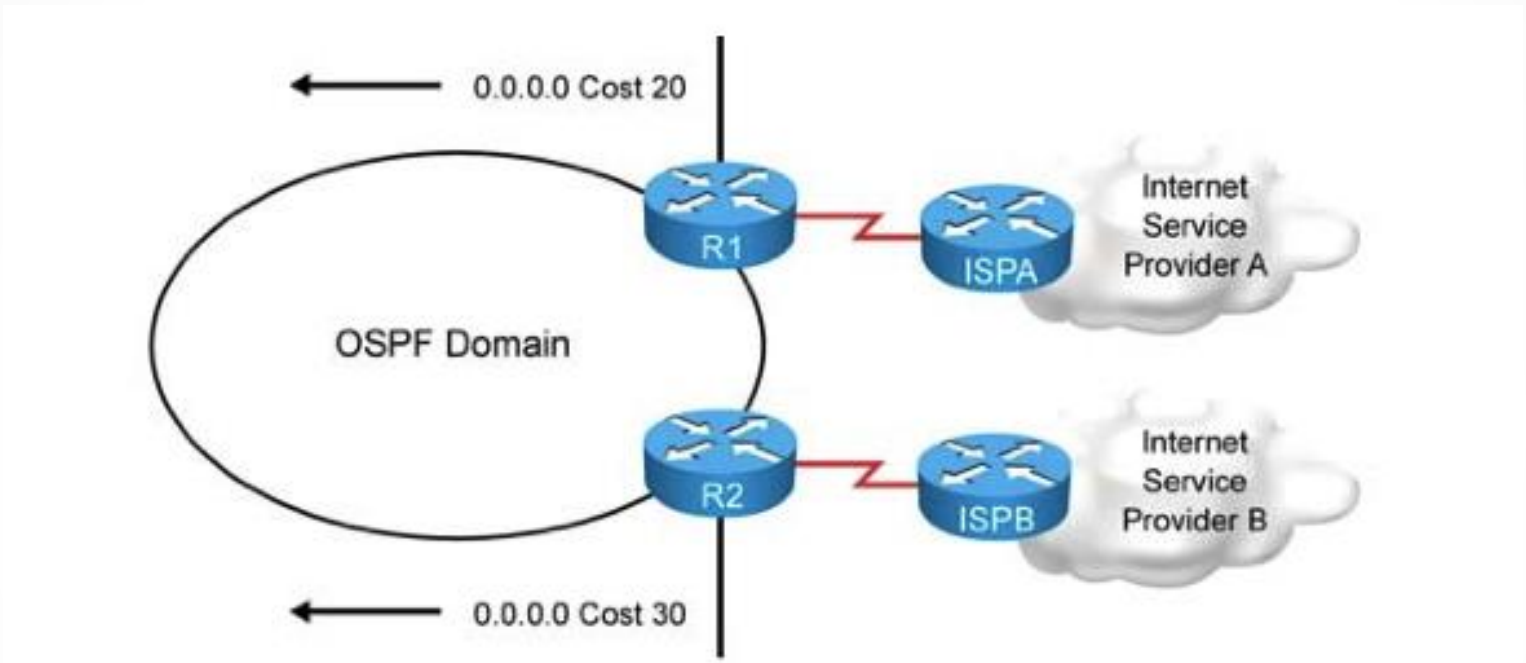
OSPF – Default Routes




```
R1(config)# router ospf 100
R1(config-router)# network 10.1.1.1 0.0.0.0 area 0
R1(config-router)# default-information originate metric 20
R1(config-router)# ip route 0.0.0.0 0.0.0.0 198.1.1.2
```

```
R2(config)# router ospf 100
R2(config-router)# network 10.2.1.1 0.0.0.0 area 0
R2(config-router)# default-information originate metric 30
R2(config-router)# ip route 0.0.0.0 0.0.0.0 198.2.1.2
```

OSPF – Default Routes



R1

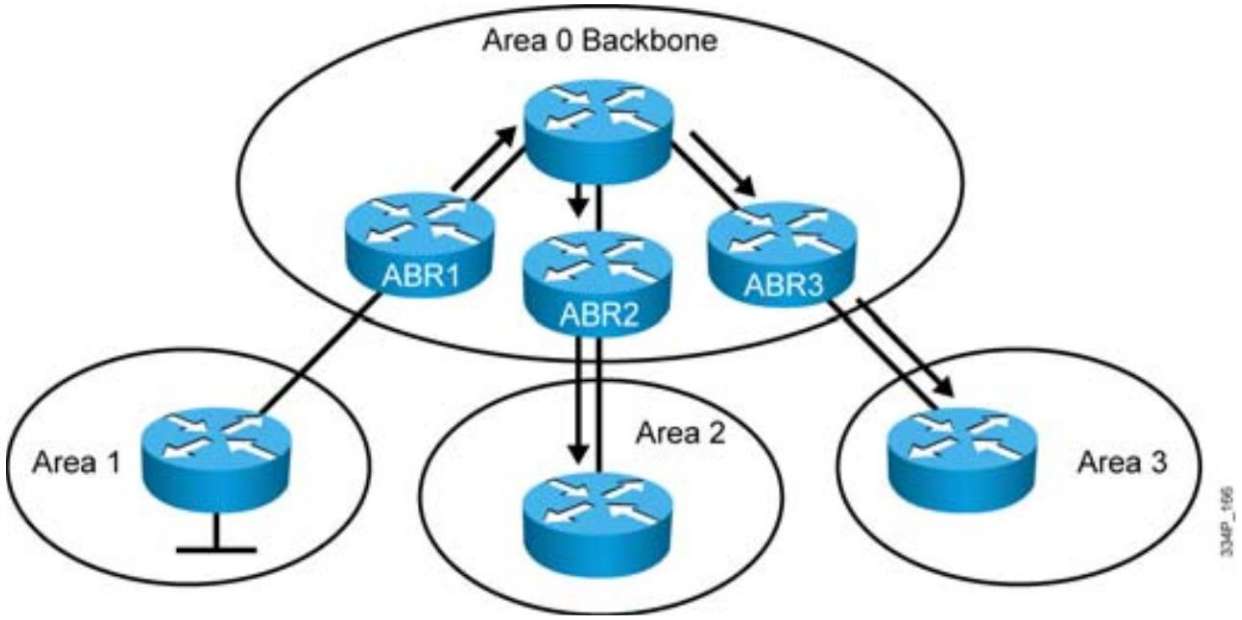
```
nv set vrf default router ospf enable on
nv set interface swp1 router ospf area 0
nv set vrf default router static 0.0.0.0/0 via 198.1.1.2
nv set vrf default router ospf default-originate enable on
nv set vrf default router ospf default-originate metric 20
```

R2

```
nv set vrf default router ospf enable on
nv set interface swp1 router ospf area 0
nv set vrf default router static 0.0.0.0/0 via 198.2.1.2
nv set vrf default router ospf default-originate enable on
nv set vrf default router ospf default-originate metric 30
```

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.



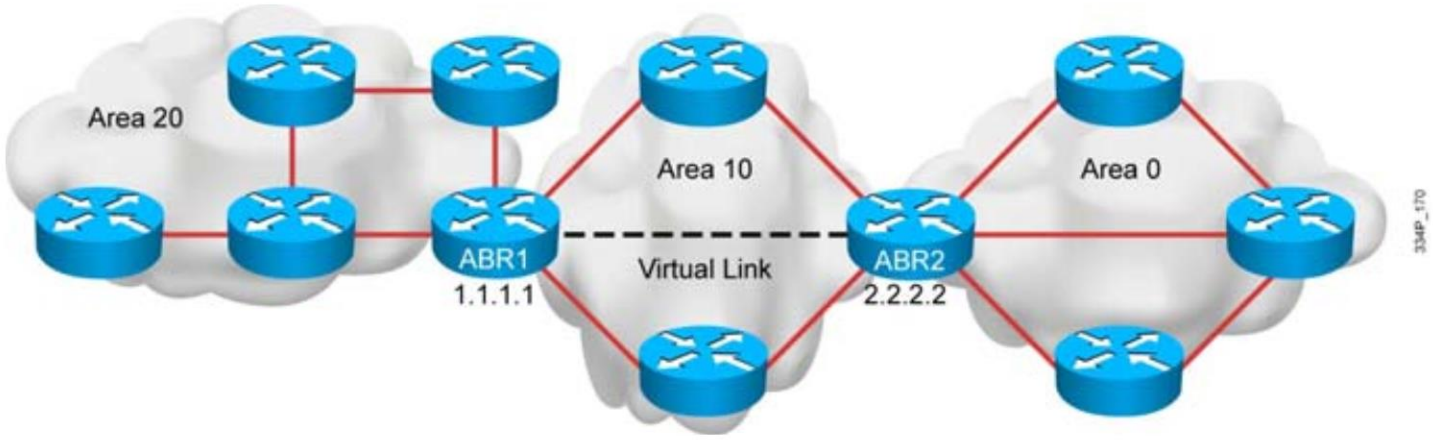
OSPF – Virtual Links as a solution

- 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)

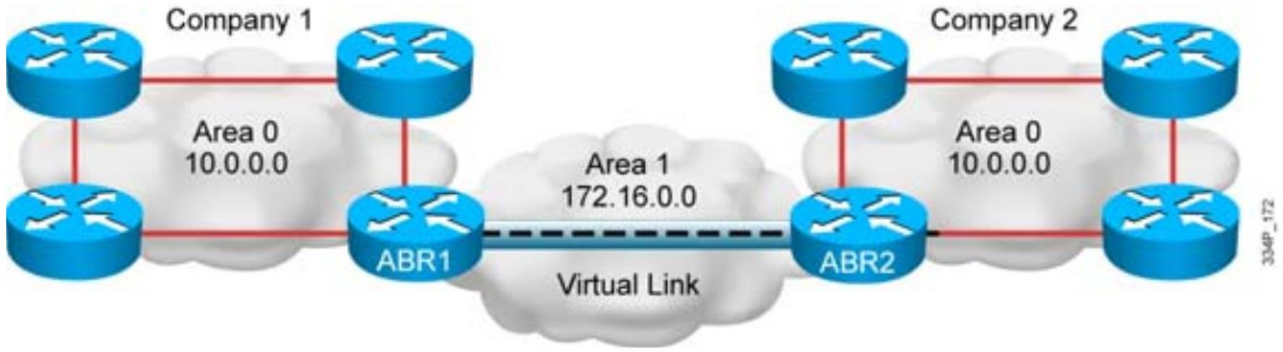
OSPF – Virtual Links

- 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



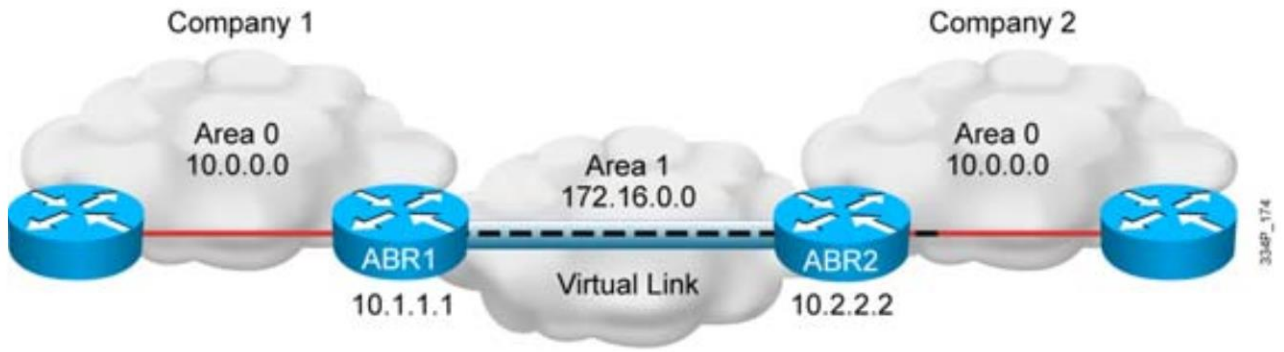
OSPF – Virtual Links

- 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.



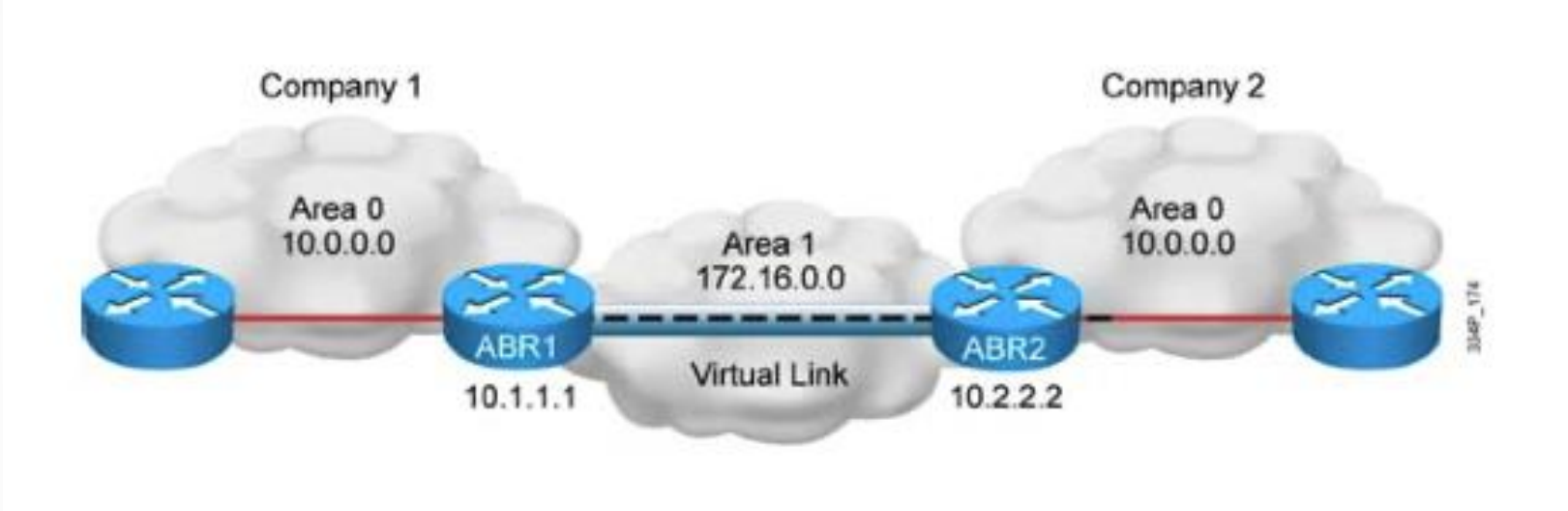
ABR1#

```
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 Configuration



ABR1

```
nv set vrf default router ospf enable on
nv set vrf default router ospf router-id 10.1.1.1

nv set interface swp1 ip address 172.16.1.1/16
nv set interface swp1 router ospf area 1
nv set interface swp2 ip address 10.1.1.1/8
nv set interface swp2 router ospf area 0

nv set vrf default router ospf area 1 virtual-link 10.2.2.2
```

ABR2

```
nv set vrf default router ospf enable on
nv set vrf default router ospf router-id 10.2.2.2

nv set interface swp1 ip address 172.16.2.1/16
nv set interface swp1 router ospf area 1
nv set interface swp2 ip address 10.2.2.2/8
nv set interface swp2 router ospf area 0

nv set vrf default router ospf area 1 virtual-link 10.1.1.1
```

OSPF – Virtual Links Verification

```
nv show vrf default router ospf area 1 virtual-link
```

```
cumulus@switch:~$ nv show vrf default router ospf area 1 virtual-link

Virtual-Link  State  Cost  Hello-Interval  Dead-Interval  Retransmit  Transmit-Delay
------------  -----  ----  --------------  -------------  ----------  --------------
10.2.2.2      Up     10    10              40             5           1
```