

Enable OSPF Routing

- Define OSPF as the IP routing protocol.

Router (config) #

```
router ospf process-id
```

- The *process-id* is an internally used number that identifies the OSPF routing process.
 - The *process-id* does not need to match process IDs on other routers
 - It can be any positive integer in the range from 1 to 65535.

Identify OSPF Networks

- Define OSPF networks to advertise to OSPF neighbors.

```
Router(config-router) #
```

```
network ip-address [wildcard-mask] area area-id
```

- The *ip-address* parameter can be a network, a subnet, or the address of a directly connected interface.
- The *wildcard-mask* is an inverse mask used to determine how to interpret the address.
 - The mask has wildcard bits, where 0 is a match and 1 is “don’t care.”
 - For example, 0.0.255.255 indicates a match in the first 2 octets.
- The *area-id* parameter specifies the OSPF area to be associated with the address.

The Wildcard Mask

- Recall that a wildcard mask is the inverse of a subnet mask.
- An easy way to calculate the inverse of the subnet mask, is to subtract the subnet mask from **255 . 255 . 255 . 255**.
- For example, the inverse of subnet mask **255 . 255 . 255 . 252** is **0 . 0 . 0 . 3**.

$$\begin{array}{r} 255 . 255 . 255 . 255 \\ - 255 . 255 . 255 . 252 \\ \hline 0 . 0 . 0 . 3 \end{array}$$

Identify OSPF Networks

- Optional method to enable OSPF explicitly on an interface.

Router (config-if) #

```
ip ospf process-id area area-id
```

- The *process-id* parameter can be a network, a subnet, or the address of a directly connected interface.
- The *area-id* parameter specifies the OSPF area to be associated with the address.
- Because this command is configured explicitly for the interface, it takes precedence over the **network area** command.

Define the Interface Bandwidth

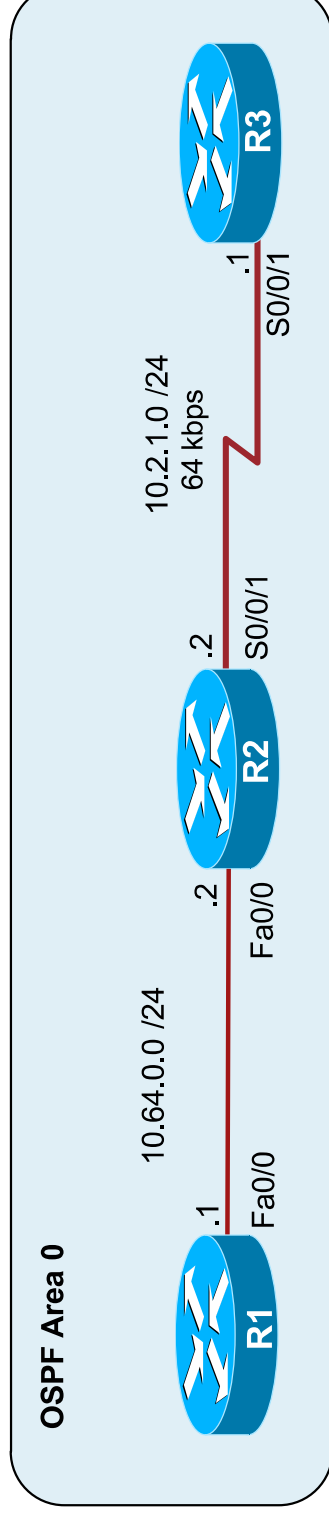
- Defines the interface's bandwidth (optional).

```
Router(config-if) #
```

```
bandwidth kilobits
```

- The *kilobits* parameter indicates the intended bandwidth in kbps.
 - For example, to set the bandwidth to 512,000 bps, use the **bandwidth 512** command.
- The configured bandwidth is used by routing protocols in the metric calculation.
- The command does not actually change the speed of the interface.

Configuring Single-Area OSPF Example

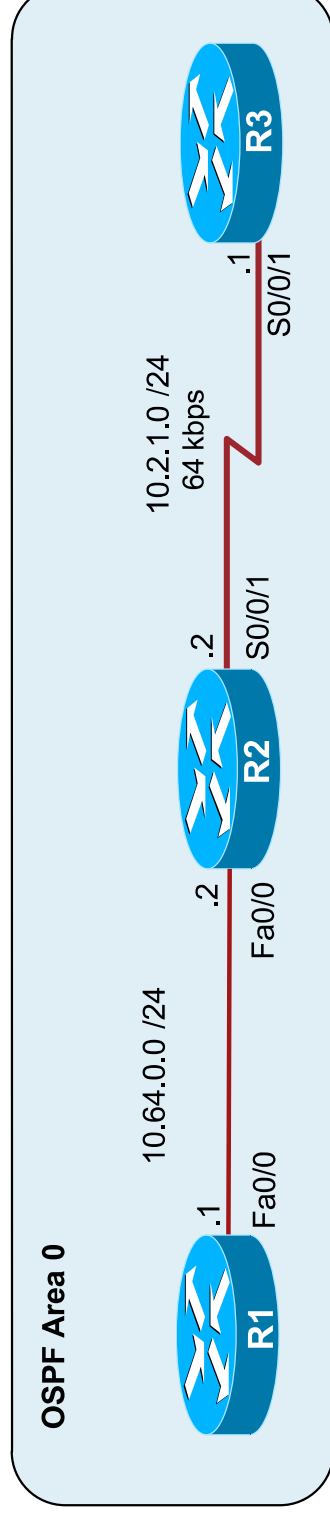


```
R1(config)# interface Fa0/0
R1(config-if)# ip address 10.64.0.1 255.255.255.0
R1(config-if)# no shut
R1(config-if)# exit
R1(config)#
```

```
R2(config)# interface Fa0/0
R2(config-if)# ip address 10.64.0.2 255.255.255.0
R2(config-if)# no shut
R2(config-if)# interface S0/0/1
R2(config-if)# ip address 10.2.1.2 255.255.255.0
R2(config-if)# bandwidth 64
R2(config-if)# no shut
R2(config-if)# exit
R2(config)#
```

```
R3(config)# interface S0/0/1
R3(config-if)# ip address 10.2.1.1 255.255.255.0
R3(config-if)# bandwidth 64
R3(config-if)# no shut
R3(config-if)# exit
R3(config)#
```

Configuring Single-Area OSPF Example

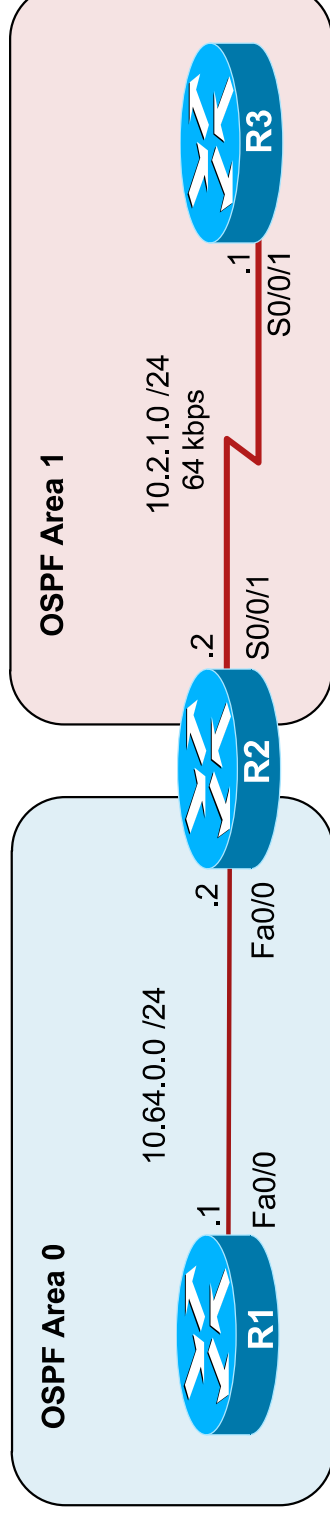


```
R1(config)# router ospf 1
R1(config-router)# network 10.0.0.0 0.255.255.255 area 0
R1(config-router)#
```

```
R2(config)# router ospf 50
R2(config-router)# network 10.2.1.2 0.0.0.0 area 0
R2(config-router)# network 10.64.0.2 0.0.0.0 area 0
R2(config-router)#
```

```
R3(config)# router ospf 100
R3(config-router)# network 10.2.1.1 0.0.0.0 area 0
R3(config-router)#
```

Configuring Multi-Area OSPF Example

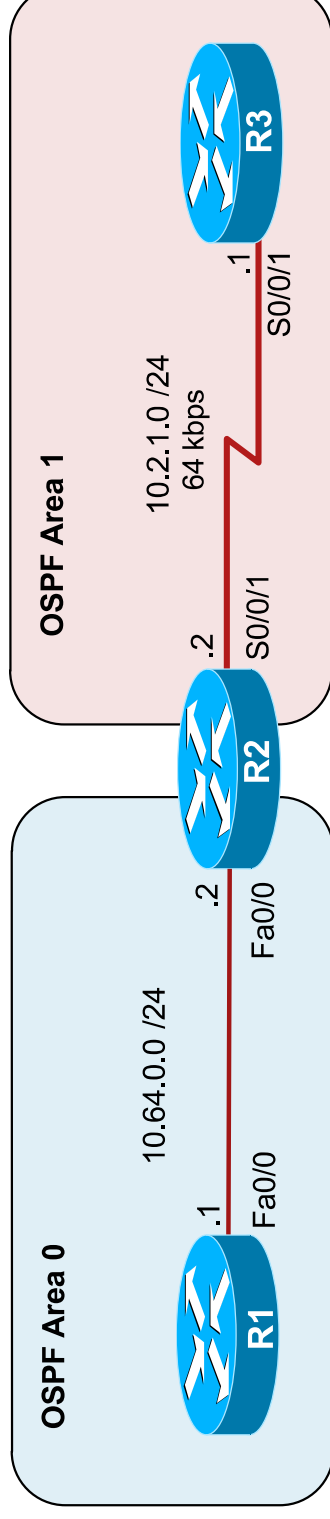


```
R1(config)# router ospf 1
R1(config-router)# network 10.0.0.0 0.255.255.255 area 0
R1(config-router)#
```

```
R2(config)# router ospf 50
R2(config-router)# network 10.2.1.2 0.0.0.0 area 1
R2(config-router)# network 10.64.0.2 0.0.0.0 area 0
R2(config-router)#
```

```
R3(config)# router ospf 100
R3(config-router)# network 10.2.1.1 0.0.0.0 area 1
R3(config-router)#
```

Alternate Multi-Area OSPF Configuration



```
R1(config)# router ospf 1
R1(config-router)# network 10.0.0.0 0.255.255.255 area 0
R1(config-router)#
```

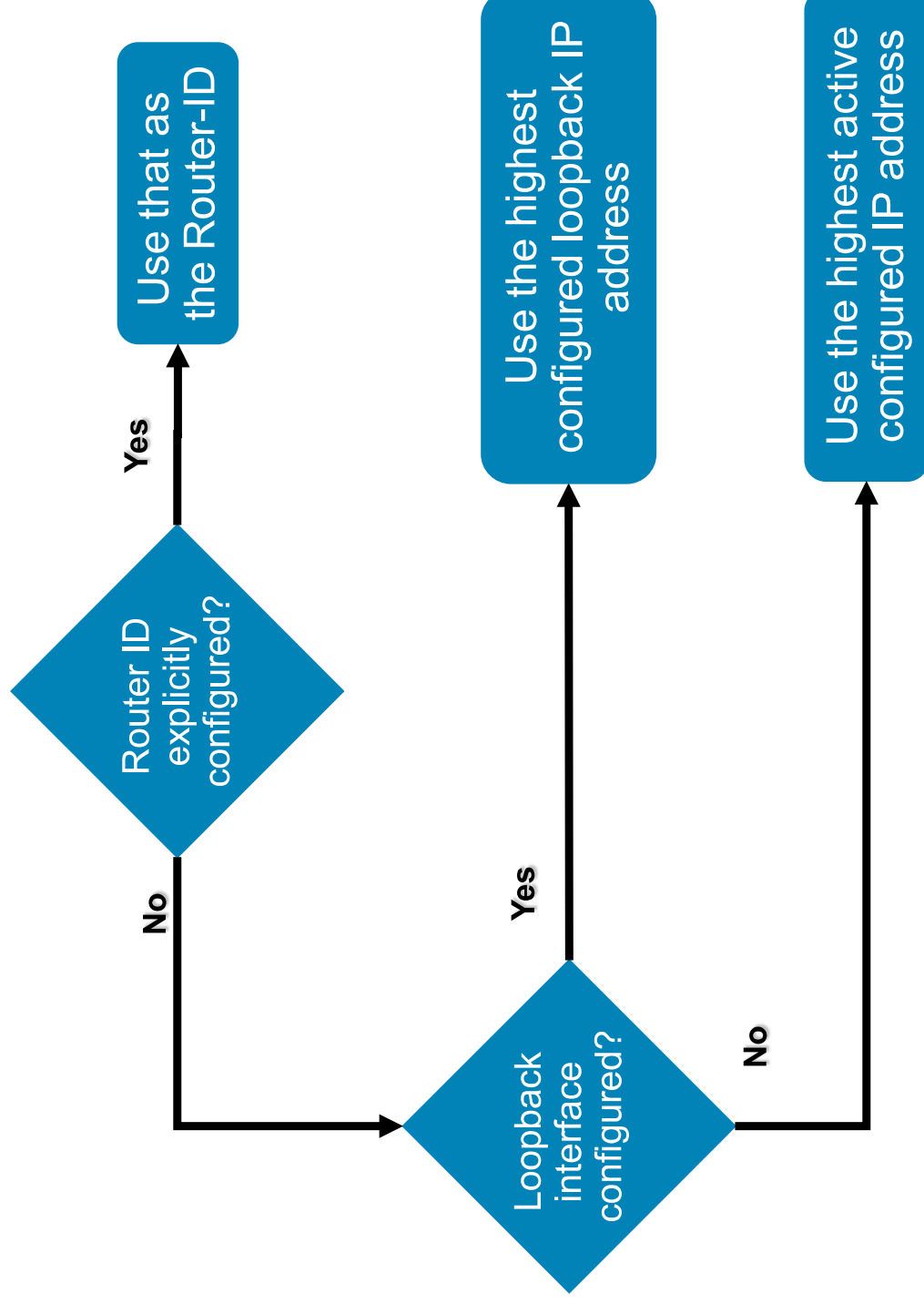
```
R2(config)# interface S0/0/1
R2(config-if)# ip ospf 50 area 1
R2(config-if)# exit
R2(config)# router ospf 50
R2(config-router)# network 10.64.0.2 0.0.0.0 area 0
R2(config-router)#
```

```
R3(config)# router ospf 100
R3(config-router)# network 10.2.1.1 0.0.0.0 area 1
R3(config-router)#
```

OSPF Router ID

- A router is known to OSPF by the OSPF router ID number.
 - LSDBs use the OSPF router ID to differentiate one router from the next.
- By default, the router ID is the highest IP address on an active interface at the moment of OSPF process startup.
 - However, for stability reason, it is recommended that the `router-id` command or a loopback interface be configured.

OSPF Router ID



Define the Router ID

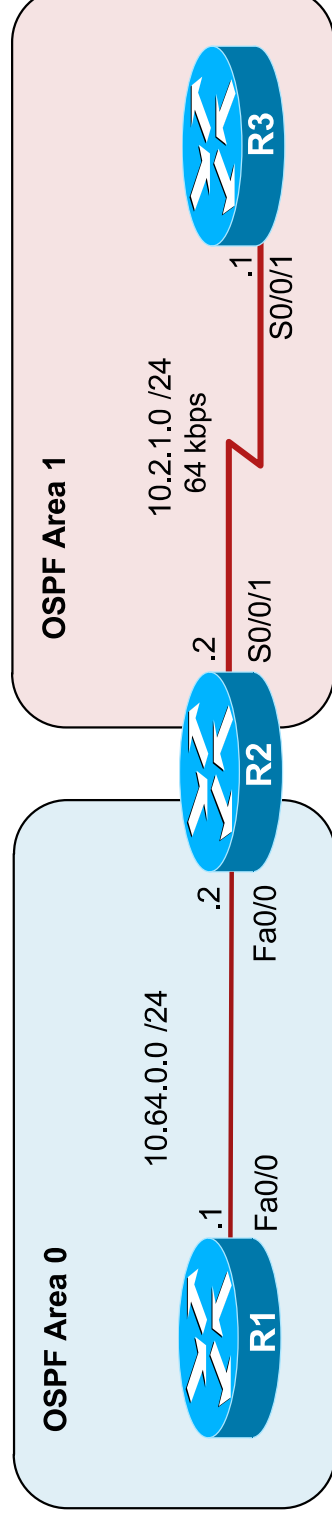
- Assign a specific router ID to the router.

Router (config-router) #

```
router-id ip-address
```

- Any unique arbitrary 32-bit value in an IP address format (dotted decimal) can be used.
- If this command is used on an OSPF process that is already active, then the new router ID takes effect:
 - After the next router reload.
 - After a manual restarting of the OSPF process using the **clear ip ospf process** privileged EXEC command.

Verifying the Router-ID



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

Verifying OSPF

Command	Description
<code>show ip protocols</code>	Displays OSPF process ID, router ID, networks router is advertising & administrative distance
<code>show ip ospf neighbors</code>	Displays OSPF neighbor relationships.
<code>show ip route</code>	Displays the routing table.
<code>show ip ospf interface</code>	Displays hello interval and dead interval
<code>show ip ospf</code>	Displays OSPF process ID, router ID, OSPF area information & the last time SPF algorithm calculated

Verifying OSPF: show ip protocols

Verify routing protocol information on the router.

```
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>
```

Verifying OSPF: show ip ospf neighbors

Display OSPF neighbors.

```
R2# show ip ospf neighbor
```

Neighbor ID	Pri	State	Dead Time	Address	Interface
10.64.0.1	1	FULL/DROTHER	00:00:30	10.64.0.1	FastEthernet0/0
10.2.1.1	1	FULL/-	00:00:34	10.2.1.1	Serial0/0/1

The interface on which this router has formed adjacency with the neighbor.

Lists the neighbors in the order they were learned.

The OSPF state of the interface. FULL state means that the router and its neighbor have identical OSPF link-state databases.

The OSPF priority of the interface.

The IP address of the neighbor's interface to which this router is directly connected.

The amount of time remaining that the router will wait to receive an OSPF Hello packet from the neighbor before declaring the neighbor down.

Verifying OSPF: show ip route ospf

Verify that the router recognizes OSPF routes.

```
R1# show ip route ospf
10.0.0.0/8 is variably subnetted, 3 subnets, 2 masks
O IA   10.2.1.0/24 [110/782] via 10.64.0.2, 00:03:05, FastEthernet0/0
R1#
```

Clearing the OSPF Routing Table

- To clear all routes from the IP routing table, use:
Router# `clear ip route *`
- To clear a specific route from the IP routing table, use:
Router# `clear ip route A.B.C.D`

Verifying OSPF: show ip ospf interface

Verify OSPF configured interfaces.

```
R1# show ip ospf interface fastEthernet 0/0
FastEthernet0/0 is up, line protocol is up
Internet Address 10.64.0.1/24, Area 0
Process ID 1, Router ID 10.64.0.1, Network Type BROADCAST, Cost: 1
Transmit Delay is 1 sec, State DROTHER, Priority 0
Designated Router (ID) 10.64.0.2, Interface address 10.64.0.2
No backup designated router on this network
Timer intervals configured, Hello 10, Dead 40, Wait 40, Retransmit 5
  oob-resync timeout 40
  Hello due in 00:00:04
Supports Link-local Signaling (LLS)
Index 1/1, flood queue length 0
Next 0x0(0)/0x0(0)
Last flood scan length is 1, maximum is 4
Last flood scan time is 0 msec, maximum is 4 msec
Neighbor Count is 1, Adjacent neighbor count is 1
  Adjacent with neighbor 10.64.0.2 (Designated Router)
Suppress hello for 0 neighbor(s)
```

Verifying OSPF: show ip ospf

Verify general OSPF information.

```
R2# show ip ospf
Routing Process "ospf 50" with ID 10.64.0.2
<output omitted>
Area BACKBONE(0)
    Area has no authentication
    SPF algorithm last executed 00:01:25.028 ago
    SPF algorithm executed 7 times
<output omitted>
Area 1
    Number of interfaces in this area is 1
    Area has no authentication
    SPF algorithm last executed 00:00:54.636 ago
    SPF algorithm executed 3 times
<output omitted>
R2#
```

Configuring and Verifying Advanced OSPF Features

OSPF Passive-Interface

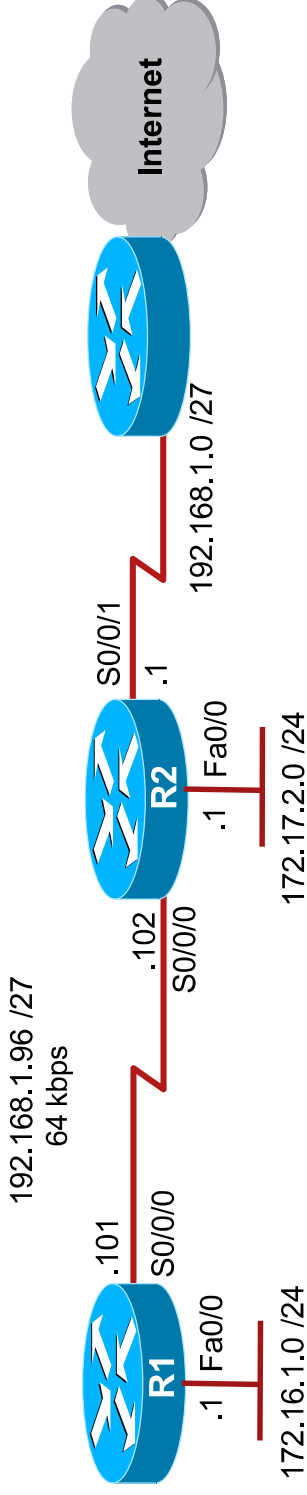
- Prevent OSPF updates out a specified router interface.

```
Router(config-router)#
```

```
passive-interface type number [default]
```

- Set a particular interface or all router interfaces to passive.
- The **default** option sets all router interfaces to passive.
- For OSPF, the command:
 - The specified interface appears as a stub network in the OSPF domain
 - The OSPF routing information is neither sent nor received through the specified router interface.
 - Prevents neighbor relationships from being established.

Passive-Interface Example



```
R1(config)# router ospf 1  
R1(config-router)# passive-interface fa0/0  
R1(config-router)#
```

```
R2(config)# router ospf 10  
R2(config-router)# passive-interface fa0/0  
R2(config-router)#
```

Alternate configuration:

```
R1(config)# router ospf 1  
R1(config-router)# passive-interface default  
R1(config-router)# no passive-interface S0/0/0
```

```
R2(config)# router ospf 10  
R2(config-router)# passive-interface default  
R2(config-router)# no passive-interface S0/0/0  
R2(config-router)# no passive-interface S0/0/1
```

Propagating a Default Route

- To propagate a default route in OSPF, use the `default-information originate` router configuration command.
- A default static route also needs to be configured on the originating router
- Once configured, the default route has to be propagated into the OSPF domain.

default-information originate Command

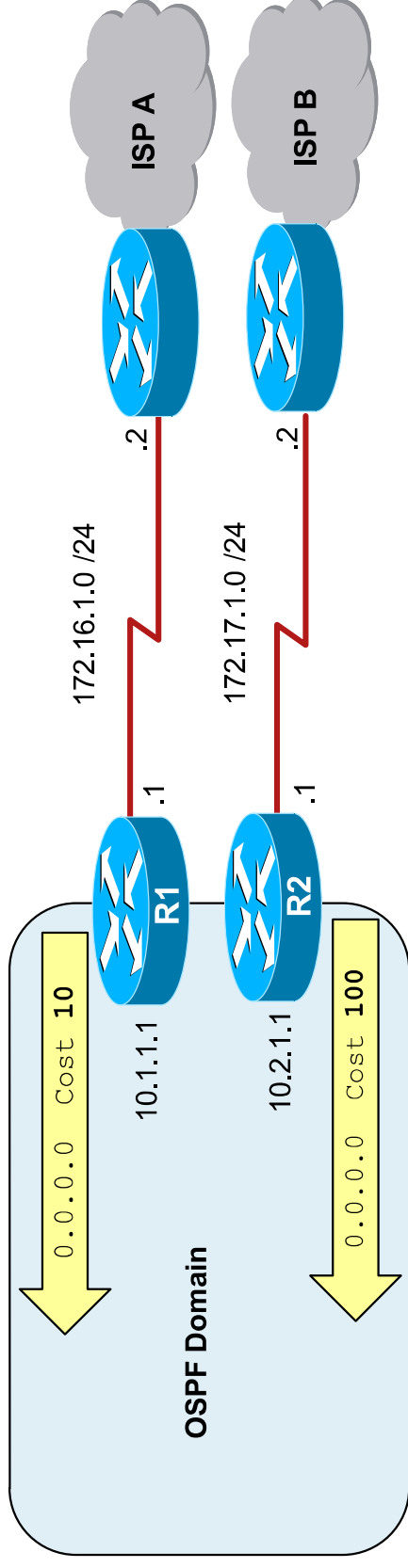
- Configures a router to generate a default external route into an OSPF routing domain.

```
Router(config-router)#
```

```
default-information originate [always] [metric metric-value]  
[metric-type type-value] [route-map map-name]
```

Parameter	Description
always	(Optional) Specifies that OSPF always advertises the default route regardless of whether the router has a default route in the routing table.
metric <i>metric-value</i>	(Optional) A metric used for generating the default route. If you omit a value and do not specify a value using the default-metric router configuration command, the default metric value is 1. Cisco IOS Software documentation indicates that the default metric value is 10; testing shows that it is actually 1.
metric-type <i>type-value</i>	(Optional) The external link type that is associated with the default route that is advertised into the OSPF routing domain. It can be one of the following values: 1—Type 1 external route 2—Type 2 external route. The default is type 2 external route (indicated by O*E2 in the routing table).
route-map <i>map-name</i>	(Optional) Specifies that the routing process generates the default route if the route map is satisfied.

default-information originate Example



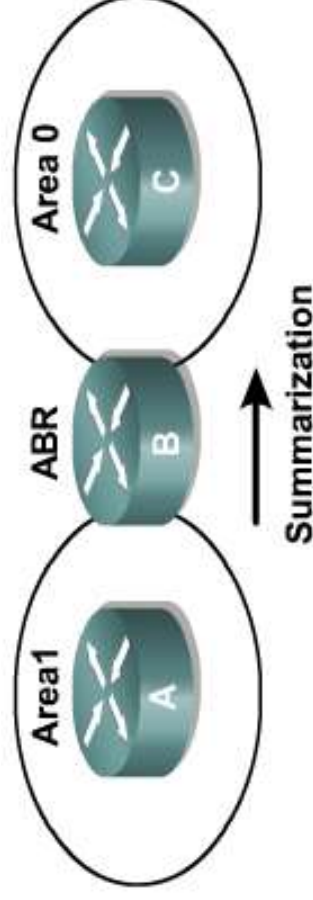
```
R1(config)# router ospf 1
R1(config-router)# network 10.1.1.1 0.0.0.0 area 0
R1(config-router)# default-information originate metric 10
R1(config-router)# exit
R1(config)# ip route 0.0.0.0 0.0.0.0 172.16.1.2
R1(config)#
```

```
R2(config)# router ospf 1
R2(config-router)# network 10.2.1.1 0.0.0.0 area 0
R2(config-router)# default-information originate metric 100
R2(config-router)# exit
R2(config)# ip route 0.0.0.0 0.0.0.0 172.17.1.2
R2(config)#
```

Route Summarization

- Route summarization involves consolidating multiple routes into a single advertisement.
- Proper route summarization directly affects the bandwidth, memory and CPU, that are consumed by the OSPF process.
 - If a network link fails or flaps, the topology change will not be propagated into the backbone or other areas.
 - It protects routers from needless routing table recalculations.
 - Because the SPF calculation places a significant demand on the router's CPU, proper summarization is an imperative part of OSPF configuration.

Using Route Summarization



Routing Table for B

```
0 172.16.8.0 255.255.255.0
0 172.16.9.0 255.255.255.0
0 172.16.10.0 255.255.255.0
0 172.16.11.0 255.255.255.0
0 172.16.12.0 255.255.255.0
0 172.16.13.0 255.255.255.0
0 172.16.14.0 255.255.255.0
0 172.16.15.0 255.255.255.0
0 172.16.16.0 255.255.255.0
0 172.16.17.0 255.255.255.0
0 172.16.18.0 255.255.255.0
0 172.16.19.0 255.255.255.0
```

LSAs Sent to Router C

IA 172.16.8.0 255.255.248.0

IA 172.16.16.0 255.255.252.0

- Interarea summary link carries mask.
- One or more entries can represent several subnets.

Types of Route Summarization

- Inter-area summarization
 - Performed at the ABR and creates Type 3 LSAs.
- External summarization
 - Performed at the ASBR and creates Type 5 LSAs.
- Both have the same fundamental requirement of contiguous addressing.
- If summarization is not configured correctly and there are multiple ASBRs, or multiple ABRs in an area, suboptimal routing is possible.
 - For example, summarizing overlapping ranges from two different routers can cause packets to be sent to the wrong destination.

Intra-Area Summarization

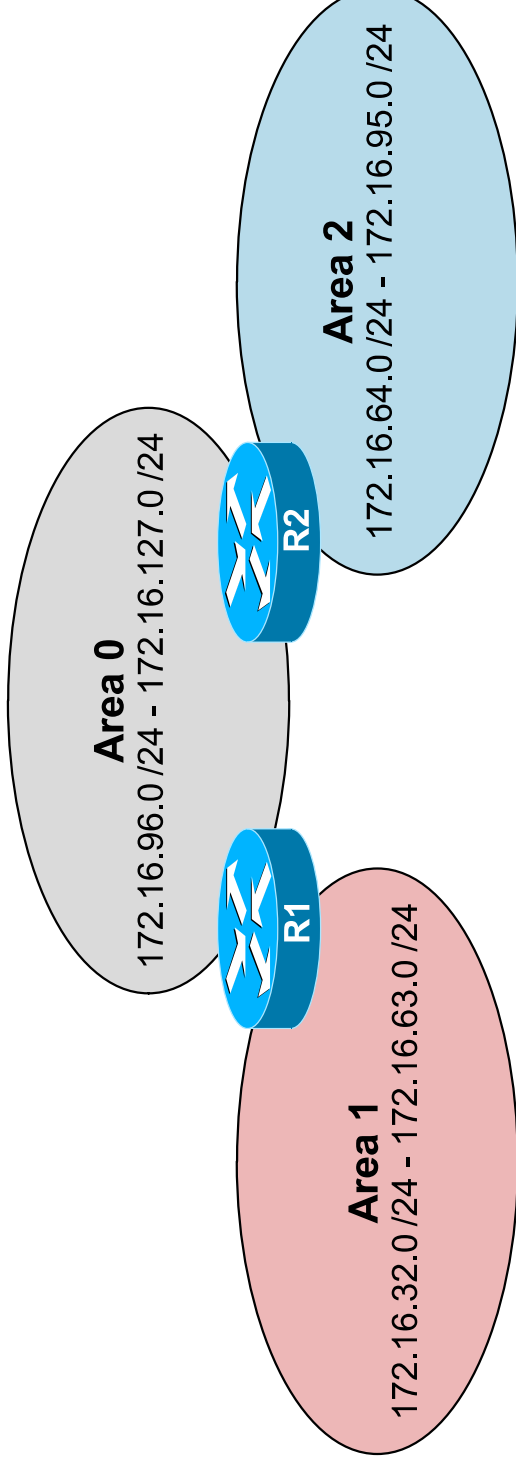
- Configure an ABR to summarize routes for a specific area.

```
Router(config-router)#
```

```
area area-id range address mask [advertise | not-advertise]  
[cost cost]
```

Parameter	Description
area <i>area-id</i>	Identifies the area subject to route summarization.
<i>address</i>	The summary address designated for a range of addresses.
<i>mask</i>	The IP subnet mask used for the summary route.
advertise	(Optional) Sets the address range status to advertise and generates a type 3 summary LSA.
not-advertise	(Optional) Sets the address range status to DoNotAdvertise. The type 3 summary LSA is suppressed, and the component networks remain hidden from other networks.
cost <i>cost</i>	(Optional) Metric or cost for this summary route, which is used during the OSPF SPF calculation to determine the shortest paths to the destination. The value can be 0 to 16777215.

Intra-Area Summarization Example



```
R1(config)# router ospf 100
R1(config-router)# network 172.16.32.1 0.0.0.0 area 1
R1(config-router)# network 172.16.96.1 0.0.0.0 area 0
R1(config-router)# area 0 range 172.16.96.0 255.255.224.0
R1(config-router)# area 1 range 172.16.32.0 255.255.224.0
R1(config-router)#
```

```
R2(config)# router ospf 100
R2(config-router)# network 172.16.64.1 0.0.0.0 area 2
R2(config-router)# network 172.16.127.1 0.0.0.0 area 0
R2(config-router)# area 0 range 172.16.96.0 255.255.224.0
R2(config-router)# area 2 range 172.16.64.0 255.255.224.0
R2(config-router)#
```

External Summarization

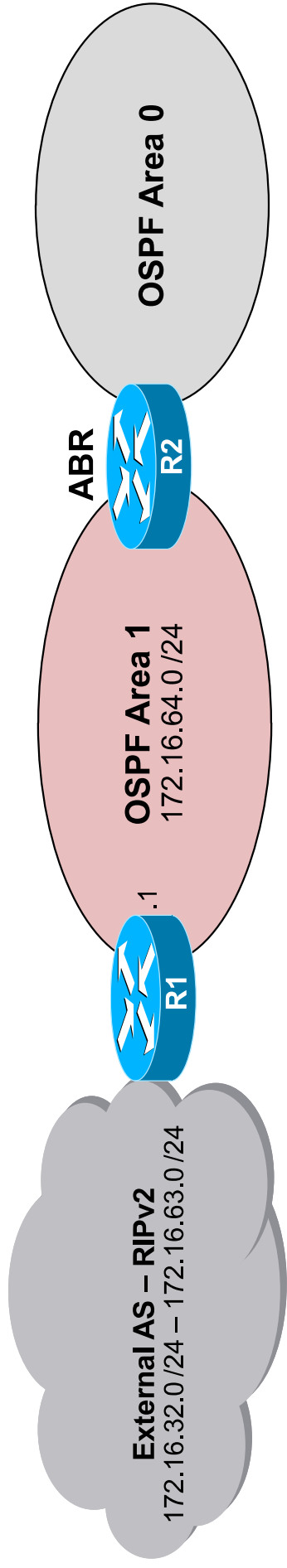
- Configure an ASBR to summarize external routes.

```
Router(config-router)#
```

```
summary-address ip-address mask [not-advertise] [tag tag]
```

Parameter	Description
<i>ip-address</i>	The summary address designated for a range of addresses.
<i>mask</i>	The IP subnet mask used for the summary route.
not-advertise	(Optional) Used to suppress routes that match the address/mask pair.
tag <i>tag</i>	(Optional) A tag value that can be used as a “match” value to control redistribution via route maps.

External Summarization



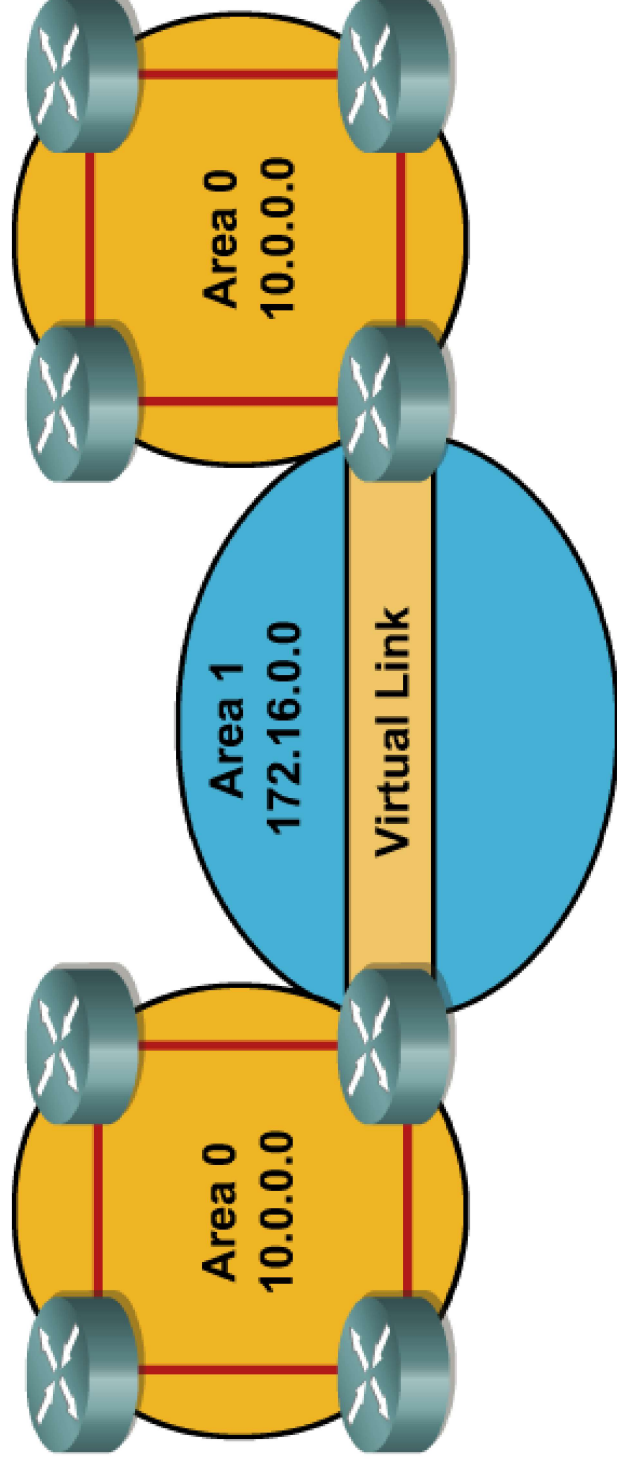
```
R1(config)# router ospf 100
```

```
R1(config-router)# network 172.16.64.1 0.0.0.0 area 1
```

```
R1(config-router)# summary-address 172.16.32.0 255.255.224.0
```

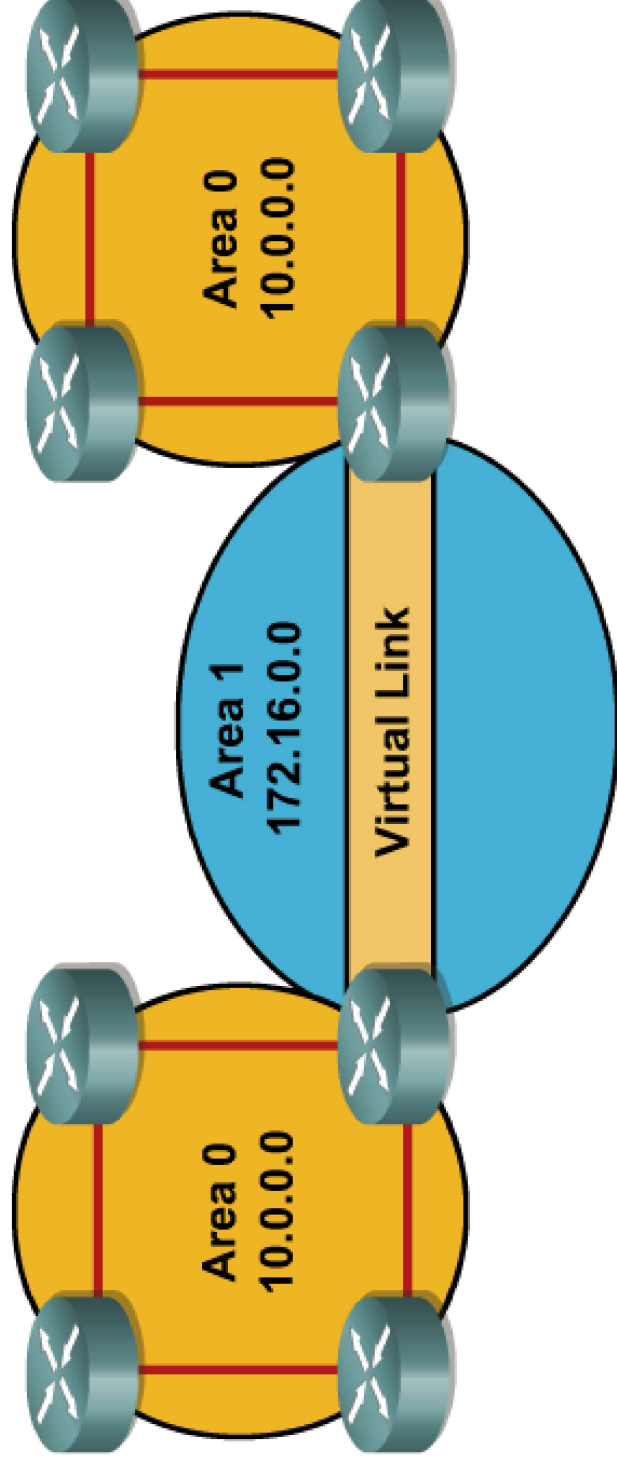
```
R1(config-router)#
```

Virtual Links



- Virtual links are used to connect a discontinuous area to area 0.
- A logical connection is built between router A and router B.
- Virtual links are recommended for backup or temporary connections.

LSAs on Virtual Links



- LSAs usually age out after 30 minutes.
- However, LSAs learned across virtual links have the DoNotAge (DNA) option set.
- Required to prevent excessive flooding over virtual links.
- To identify an area as a virtual link, use the **area** *area-id* **virtual-link** router configuration command.

Configuring Virtual Links

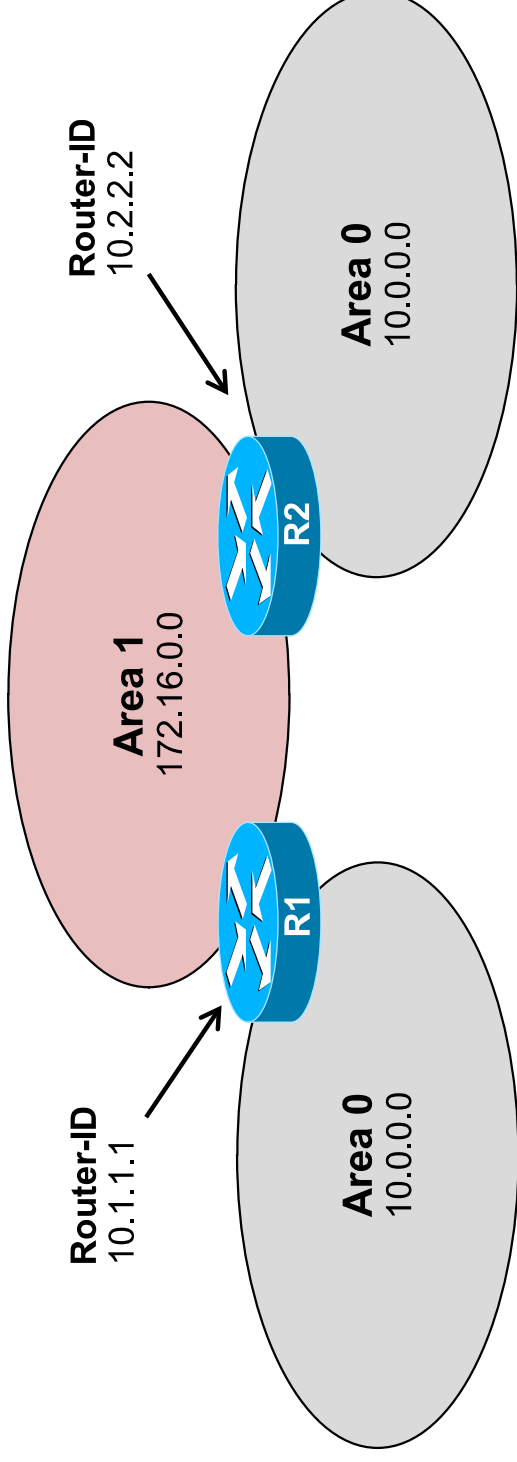
- Define an OSPF virtual link.

```
Router(config-router) #
```

```
area area-id virtual-link router-id [authentication [message-digest | null]] [hello-interval seconds] [retransmit-interval seconds] [transmit-delay seconds] [dead-interval seconds] [authentication-key key] | [message-digest-key key-id md5 key]
```

Parameter	Description
area-id	Specifies the area ID of the transit area for the virtual link.
router-id	Specifies the router ID of the virtual link neighbor.
authentication	(Optional) Specifies an authentication type.
message-digest	(Optional) Specifies the use of MD5 authentication.
null	(Optional) Overrides authentication if configured.
hello-interval <i>seconds</i>	(Optional) Specifies the time between the hello packets (default 10).
retransmit-interval <i>seconds</i>	(Optional) Specifies the time between LSA retransmissions (default 5).
transmit-delay <i>seconds</i>	(Optional) Specifies the time to send an LSU packet (default 1).
dead-interval <i>seconds</i>	(Optional) Specifies the dead-interval time (default 40).
authentication-key <i>key</i>	(Optional) Specifies the password for simple password authentication.
message-digest-key <i>key-id</i> md5 <i>key</i>	(Optional) Identifies the key ID and key for MD5 authentication.

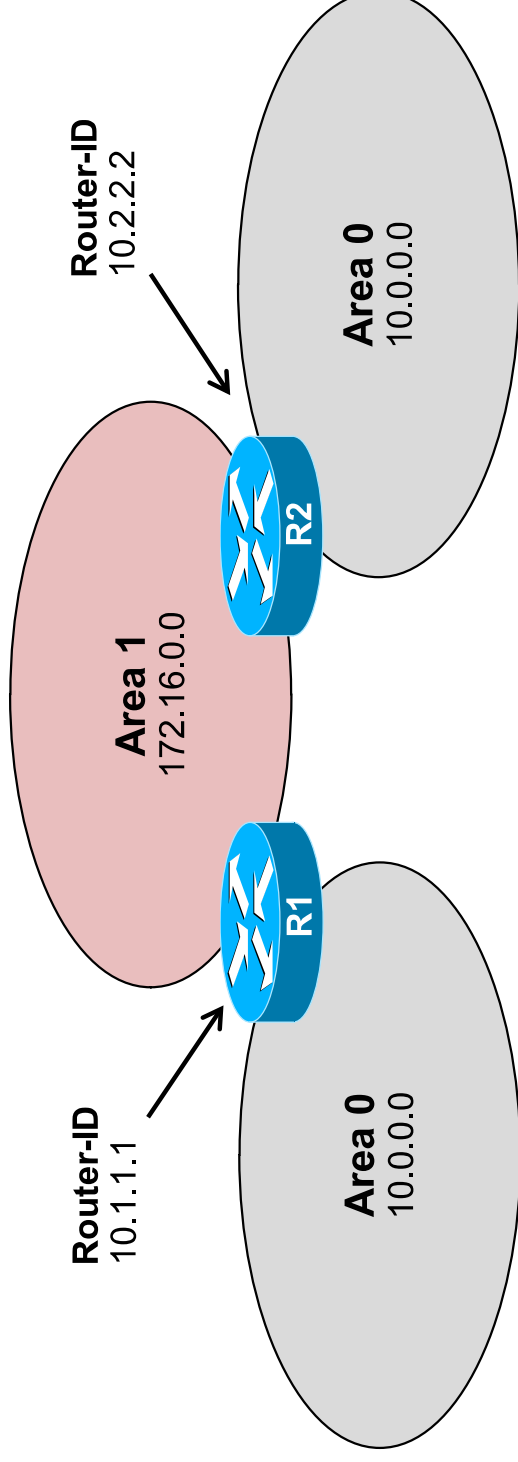
Virtual-Link Example



```
R1(config)# router ospf 100
R1(config-router)# network 172.16.0.0 0.0.255.255 area 1
R1(config-router)# network 10.0.0.0 0.0.255.255 area 0
R1(config-router)# area 1 virtual-link 10.2.2.2
R1(config-router)#
```

```
R2(config)# router ospf 100
R2(config-router)# network 172.16.0.0 0.0.255.255 area 1
R2(config-router)# network 10.0.0.0 0.0.255.255 area 0
R2(config-router)# area 1 virtual-link 10.1.1.1
R2(config-router)#
```

Verifying a Virtual-Link Example



```
R1# 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
```

```
R1#
```

Changing the Reference Bandwidth

Interface Type	$10^8/\text{bps} = \text{Cost}$
Fast Ethernet and faster	$10^8/100,000,000 \text{ bps} = 1$
Ethernet	$10^8/10,000,000 \text{ bps} = 10$
E1	$10^8/2,048,000 \text{ bps} = 48$
T1	$10^8/1,544,000 \text{ bps} = 64$
128 kbps	$10^8/128,000 \text{ bps} = 781$
64 kbps	$10^8/64,000 \text{ bps} = 1562$
56 kbps	$10^8/56,000 \text{ bps} = 1785$

- The reference bandwidth defaults to 10^8 (100,000,000 bps or 100 Mbps).
- This can be a problem when using interfaces faster than 100 Mbps and higher since they would all have the same OSPF cost of 1.
- The reference bandwidth can be modified using the **auto-cost reference-bandwidth** router configuration command.

Changing the Reference Bandwidth

- Change the reference bandwidth for faster interfaces.

```
Router(config-router) #
```

```
auto-cost reference-bandwidth ref-bw
```

- The *ref-bw* parameter is the reference bandwidth in megabits per second.
 - The range is from 1 to 4,294,967.
 - The default is 100.
- Use this command if interfaces are faster than 100 Mbps.
 - The command must be configured on all OSPF routers to ensure accurate route calculations.

Modifying the Cost of a Link

- The cost of a link can be modified using either the:
 - `bandwidth` interface command
 - `ip ospf cost` interface command
- The configured `bandwidth` *value* is used by the SPF algorithm to calculate the cost.
 - For example, configuring the `bandwidth 128` command on a serial interface would generate a cost of 1,562.
 - $\text{Cost} = 100,000,000 / 128,000 = 1,562$.
- Using the `ip ospf cost` interface command achieves the same result without the calculation.
 - For example, the interface cost could be statically configured using the `ip ospf cost 1562` command.

Override the Default Interface Cost

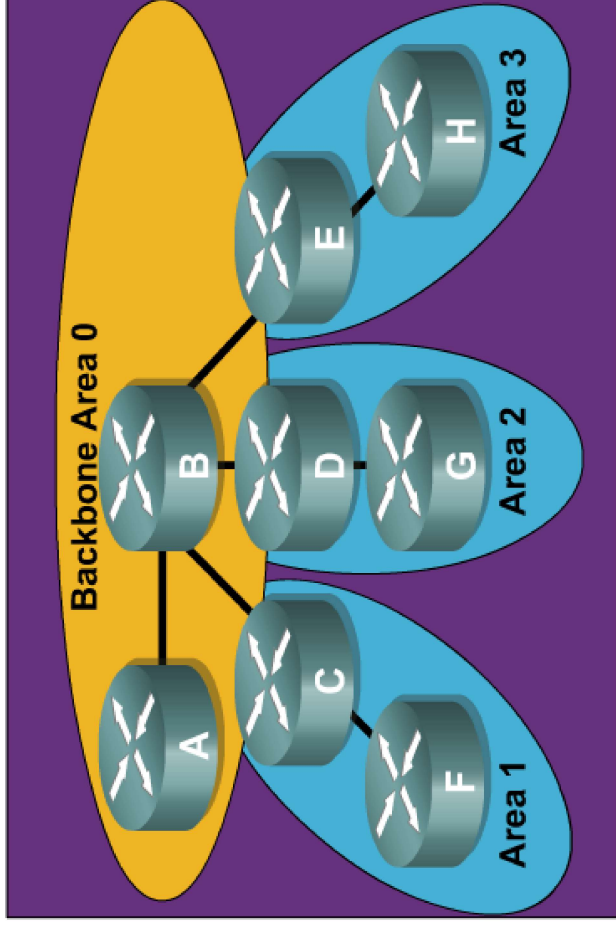
- Manually define the cost of an interface.

```
Router (config-if) #
```

```
ip ospf cost interface-cost
```

- The *interface-cost* is an integer from 1 to 65,535.
 - The lower the number, the better (and more preferred) the link.
 - Can be used as an alternative to the **bandwidth** command.

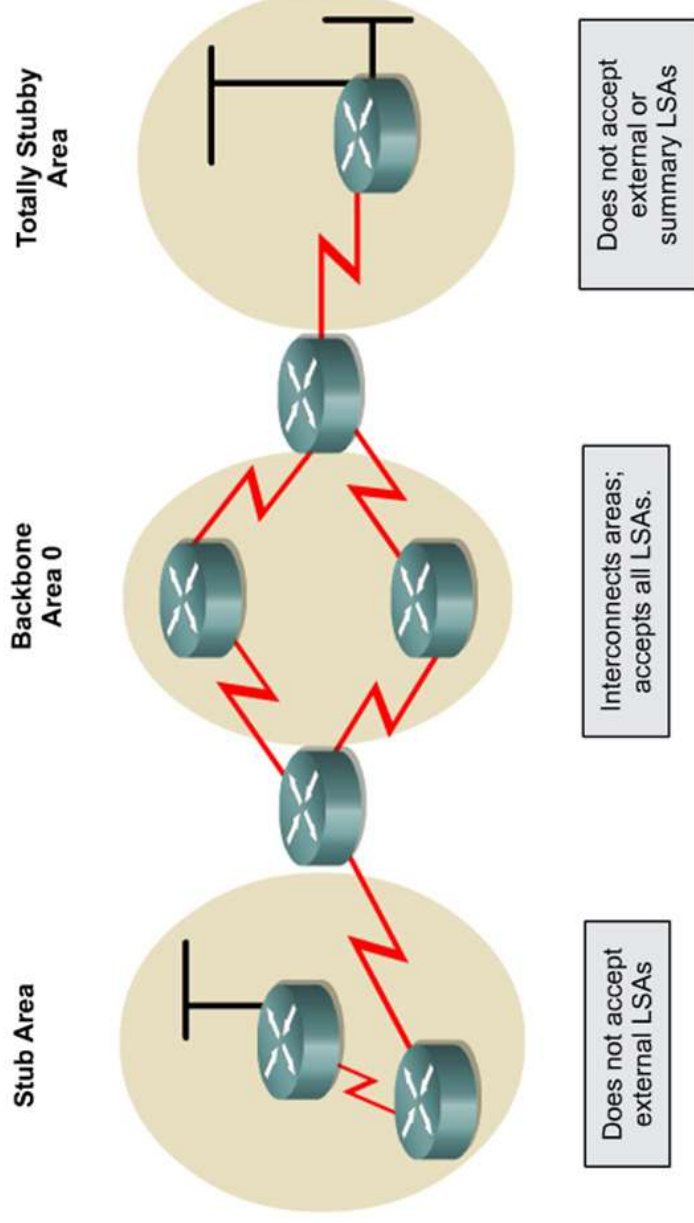
OSPF Two-Layer Hierarchy - Review



- **Backbone Area**
 - Referred to as Area 0
 - Also known as the Transit Area.
- **Regular (Standard) Areas**
 - Also known as a nonbackbone areas.
 - All regular areas must connect to the backbone area.

OSPF Special Area Types

- The OSPF standard area can be further divided into four types of stub areas:
 - Stub area
 - Totally stubby area
 - NSSA
 - Totally stubby NSSA



OSPF Area Types

Area Type	Accepts routes within area (O)	Accepts routes from other areas (O IA)	Accepts external routes (O E1 and O E2)	Allows ASBR	Cisco proprietary
Standard	Yes	Yes	Yes	Yes	No
Backbone	Yes	Yes	Yes	Yes	No
Stub	Yes	Yes	No (uses default route)	No	No
Totally stubby	Yes	No (uses default route)	No (uses default route)	No	Yes
NSSA	Yes	Yes	No (uses default route)	Yes	No
Totally stubby NSSA	Yes	No (uses default route)	No (uses default route)	Yes	Yes

Stub and Totally Stub Area Characteristics

- An area qualifies as stub or totally stubby area if it has the following characteristics:
 - The area is not the backbone area (area 0).
 - There is a single exit point from that area.
 - If there are multiple exits, one or more ABRs should inject a default route into the stub area however suboptimal routing paths might occur.
 - There is no ASBR inside the area.
 - The area is not used as a transit area for virtual links.

Stub and Totally Stub Area Characteristics

- All OSPF routers inside the stub area, including ABRs, are configured as stub routers using the **area** *area-id* **stub** router configuration command.
- By default, the ABR of a stubby or totally stubby area advertises a default route with a cost of 1.
 - To change the cost of the default route, use the **area** *area-id* **default-cost** *cost* router configuration command.

Configure a Stub Area

- Identify an area as a stub network.

```
Router (config-router) #
```

```
area area-id stub
```

- The *area-id* parameter is the identifier for the stub area and can be either a decimal value or a value in dotted-decimal format, like an IP address.

Change the Default Cost

- Define the cost of the default route injected into the stub stubby area.

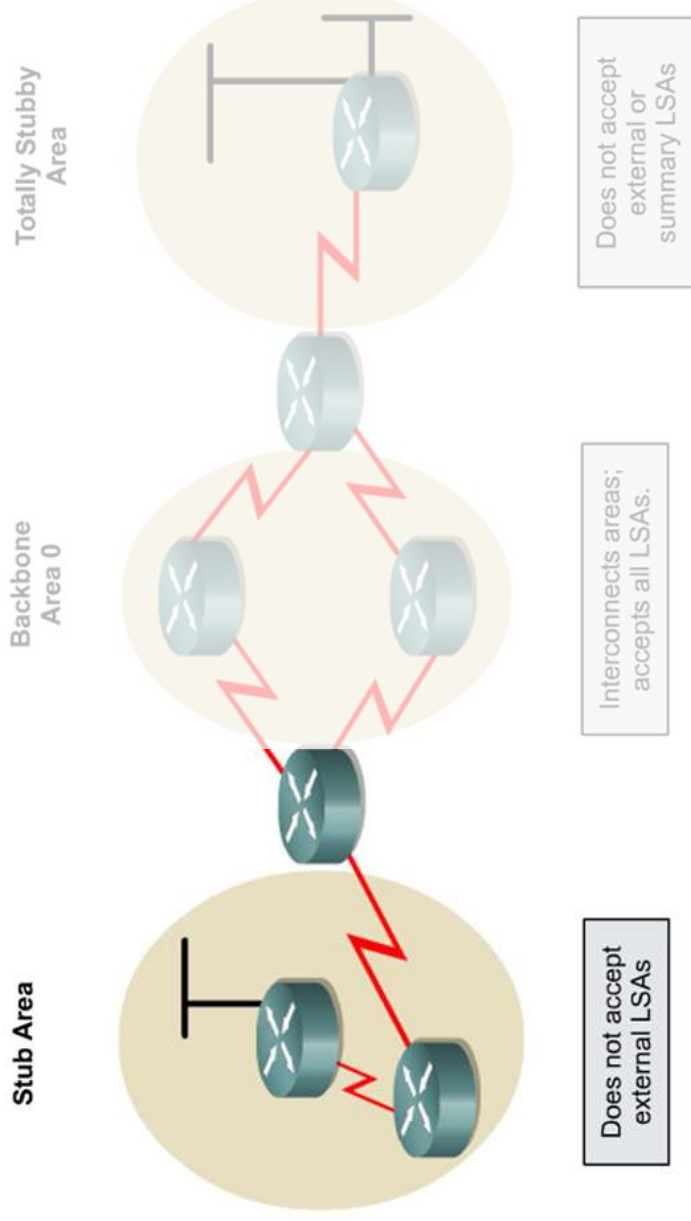
```
Router(config-router) #
```

```
area area-id default-cost cost
```

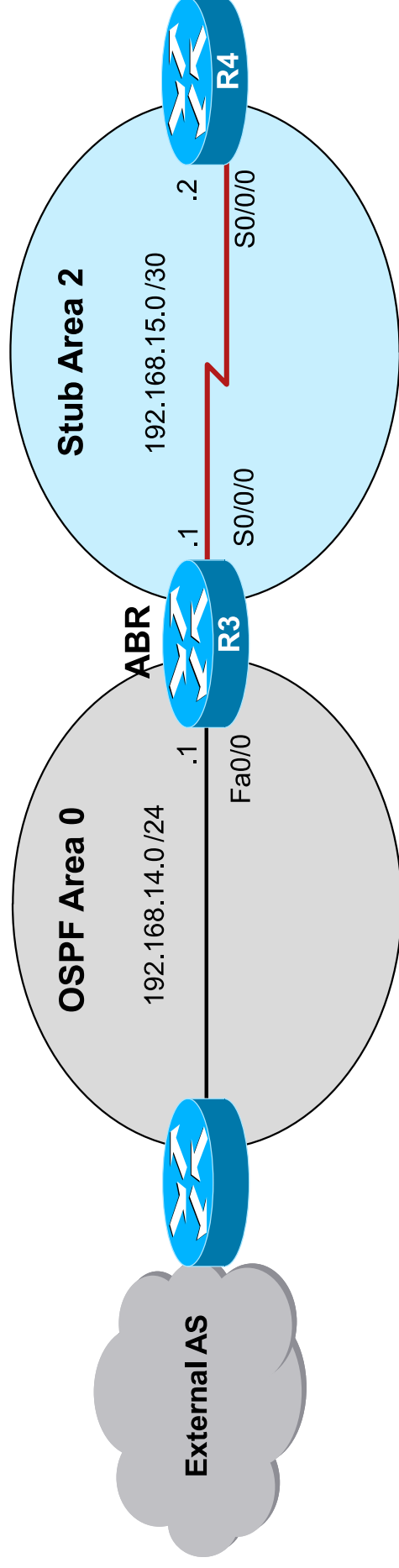
- The *cost* parameter is for the default summary route.
 - The acceptable values are 0 through 16777215.
 - The default is 1.
- If this command has not been configured, the ABR will advertise 0.0.0.0 with a default cost metric of 1 plus any internal costs.

Stub Area

- Typically used in a hub-and-spoke network.
- Area does not accept external summary routes from non-OSPF sources (e.g., RIP, EIGRP).
 - Specifically, it does not accept Types 4 and 5 LSAs.
 - A default route (0.0.0.0) is propagated throughout the area to send a packet to an external network.



Configuring a Stub Area

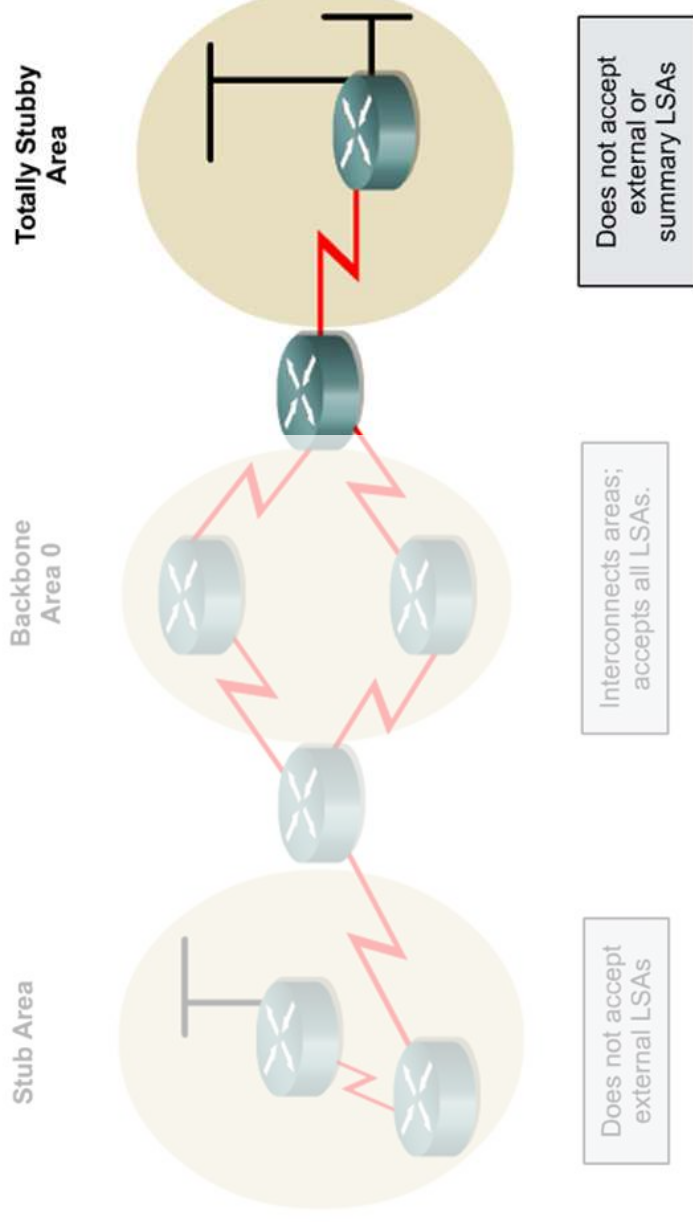


```
R3(config)# interface FastEthernet0/0
R3(config-if)# ip address 192.168.14.1 255.255.255.0
R3(config-if)# interface Serial 0/0/0
R3(config-if)# ip address 192.168.15.1 255.255.255.252
R3(config-if)# router ospf 100
R3(config-router)# network 192.168.14.0 0.0.0.255 area 0
R3(config-router)# network 192.168.15.0 0.0.0.255 area 2
R3(config-router)# area 2 stub
R3(config-router)#
```

```
R4(config-if)# interface Serial 0/0/0
R4(config-if)# ip address 192.168.15.2 255.255.255.252
R4(config-if)# router ospf 100
R4(config-router)# network 192.168.15.0 0.0.0.255 area 2
R4(config-router)# area 2 stub
R4(config-router)#
```

Totally Stubby Area

- Cisco proprietary solution that is better than stub area.
- Area does not accept external AS routes or inter-area routes.
 - Specifically, it does not accept Types 3, 4 and 5 LSAs.
 - It recognizes only intra-area routes and the default route 0.0.0.0.
 - A default route (0.0.0.0) is propagated throughout the area.



Configure a Totally Stubby Area

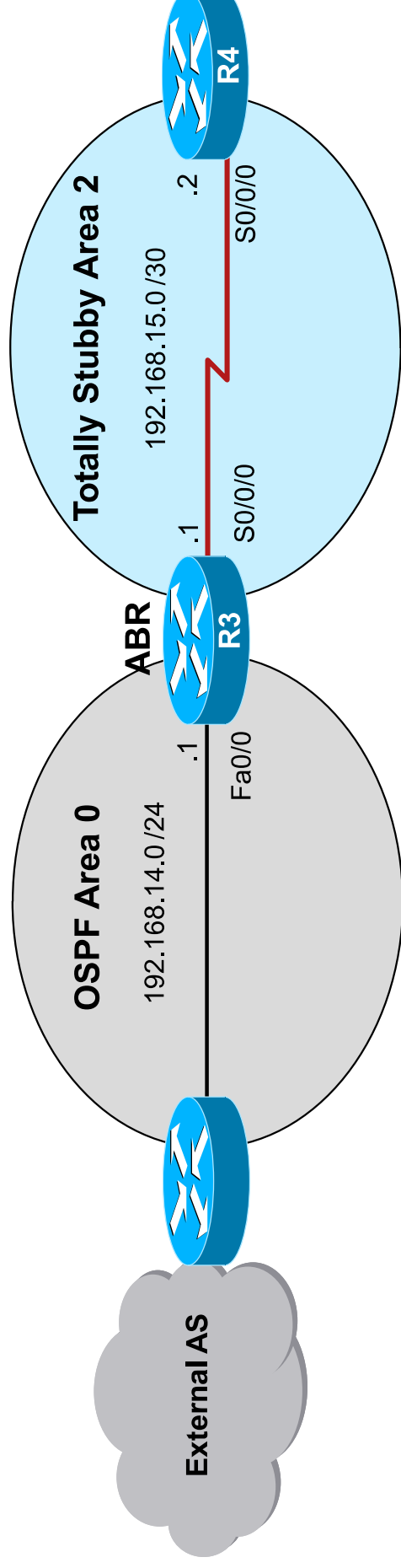
- Identify an ABR as a totally stubby network.

```
Router (config-router) #
```

```
area area-id stub no-summary
```

- Command is only configured on the ABR.
 - All other routers in the totally stubby area are configured as stub routers.
- The *area-id* parameter is the identifier for the stub area and can be either a decimal value or a value in dotted-decimal format, like an IP address.
- The **no-summary** parameter stops summary LSAs, in addition to external LSAs, from flooding into the totally stubby area.

Configuring a Totally Stubby Area

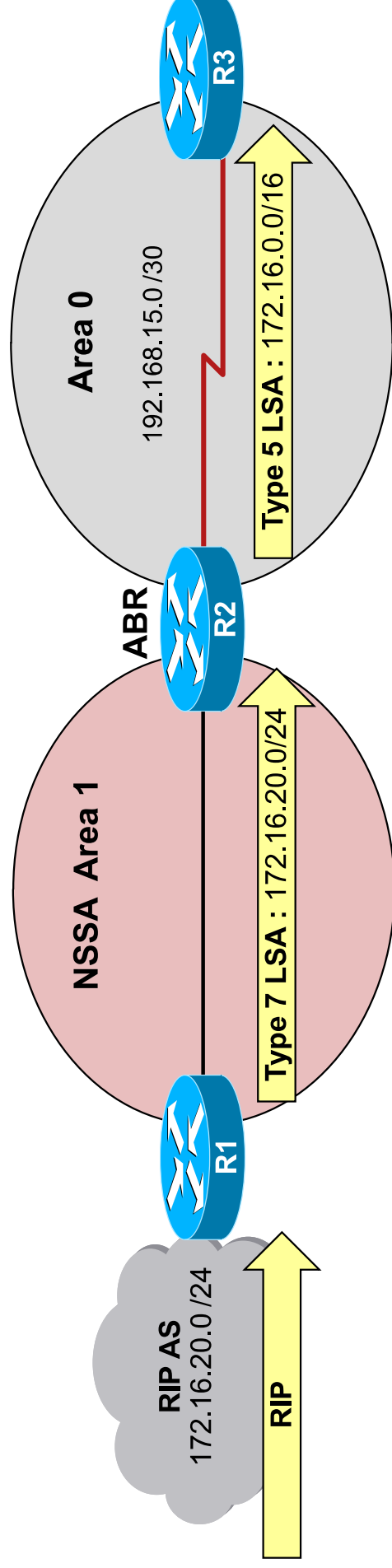


```
R3(config)# interface FastEthernet0/0
R3(config-if)# ip address 192.168.14.1 255.255.255.0
R3(config-if)# interface Serial 0/0/0
R3(config-if)# ip address 192.168.15.1 255.255.255.252
R3(config-if)# router ospf 100
R3(config-router)# network 192.168.14.0.0 0.0.0.255 area 0
R3(config-router)# network 192.168.15.0.0 0.0.0.255 area 2
R3(config-router)# area 2 stub no-summary
R3(config-router)#
```

```
R4(config-if)# interface Serial 0/0/0
R4(config-if)# ip address 192.168.15.2 255.255.255.252
R4(config-if)# router ospf 100
R4(config-router)# network 192.168.15.0.0 0.0.0.255 area 2
R4(config-router)# area 2 stub
R4(config-router)#
```

Not-So-Stubby Area (NSSA)

- Similar to a Stub Area, except that it is primarily used to connect to ISPs, or when redistribution is required.
- Specifically, it does not accept Types 4 and 5 LSAs.
- Allows the importing of external routes as Type 7 LSAs and converts them to Type 5 LSAs on the ABR.
- Better than creating stub areas and also useful for spokes.



Configure an NSSA

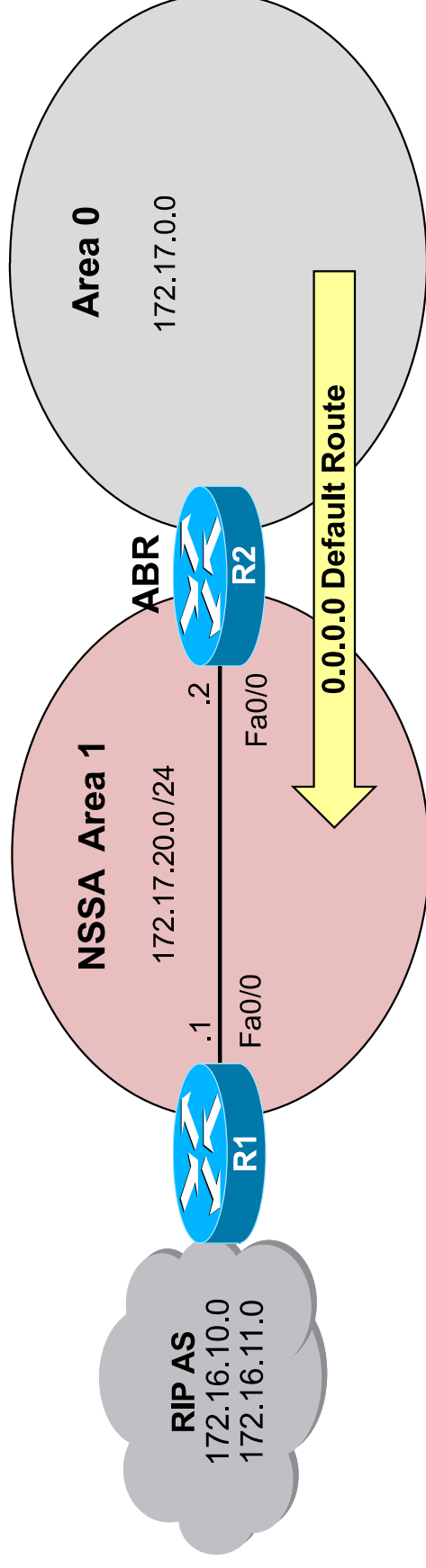
- Define an NSSA area.

```
Router(config-router)#
```

```
area area-id nssa no-redistribution [default-information-originate] [metric metric-value] [metric-type type-value] [no-summary]
```

Parameter	Description
area-id	The identifier for the NSSA.
no-redistribution	(Optional) Used when the router is an NSSA ABR and you want the redistribute command to import routes only into the standard areas, but not into the NSSA area.
default-information-originate	(Optional) Used to generate a type 7 default LSA into the NSSA area. This keyword takes effect only on an NSSA ABR or an NSSA ASBR.
metric <i>metric-value</i>	(Optional) Metric that is used for generating the default route. Acceptable values are 0 through 16777214.
metric-type <i>type-value</i>	(Optional) OSPF metric type for default routes. It can be one of the following values: type 1 external route or 2: type 2 external route
no-summary	(Optional) Allows an area to be a totally stubby NSSA, which is like an NSSA but does not have summary routes injected into it.

Configuring a NSSA Area



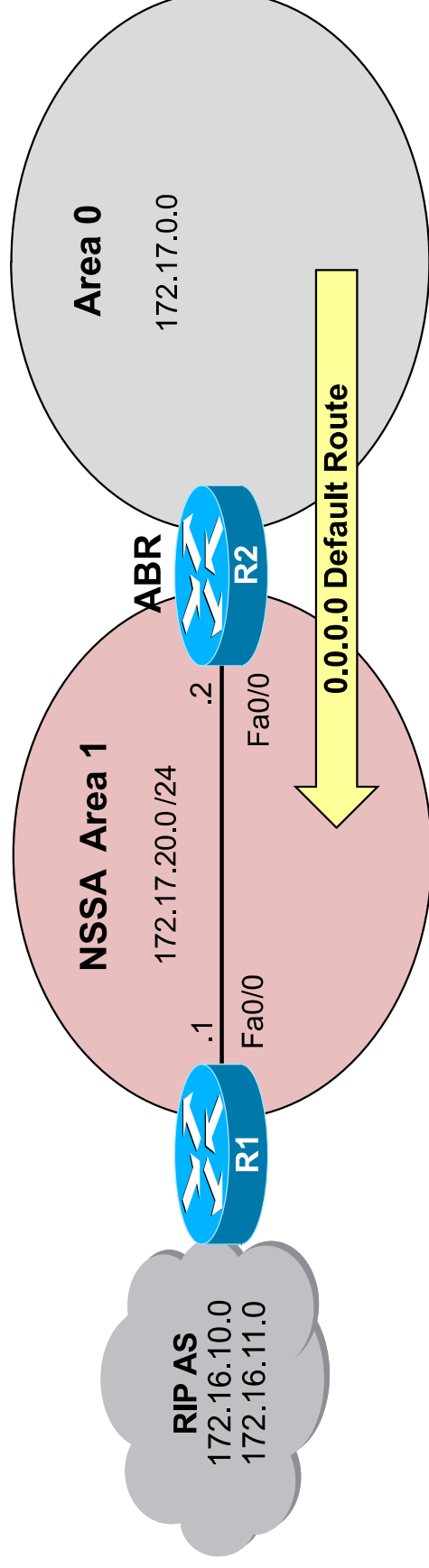
```
R1(config)# router ospf 10
R1(config-router)# redistribute rip subnets
R1(config-router)# default metric 150
R1(config-router)# network 172.17.0.0 0.0.255.255 area 1
R1(config-router)# area 1 nssa
R1(config-router)#
```

```
R2(config)# router ospf 10
R2(config-router)# summary-address 172.16.0.0 255.255.0.0
R2(config-router)# network 172.17.20.0 0.0.0.255 area 1
R2(config-router)# network 172.17.0.0 0.0.255.255 area 0
R2(config-router)# area 1 nssa default-information-originate
R2(config-router)#
```

Totally Stubby NSSA

- Cisco proprietary solution to NSSA.
- Area does not accept external AS routes or inter-area routes.
 - Specifically, it does not accept Types 3, 4 and 5 LSAs.
 - It recognizes only intra-area routes and the default route 0.0.0.0.
 - A default route (0.0.0.0) is propagated throughout the area.
- The ABR of a totally stubby NSSA must be configured with the **no-summary** keyword to prevent the flooding of summary routes for other areas into the NSSA area.

Configuring a Totally Stubby NSSA Area



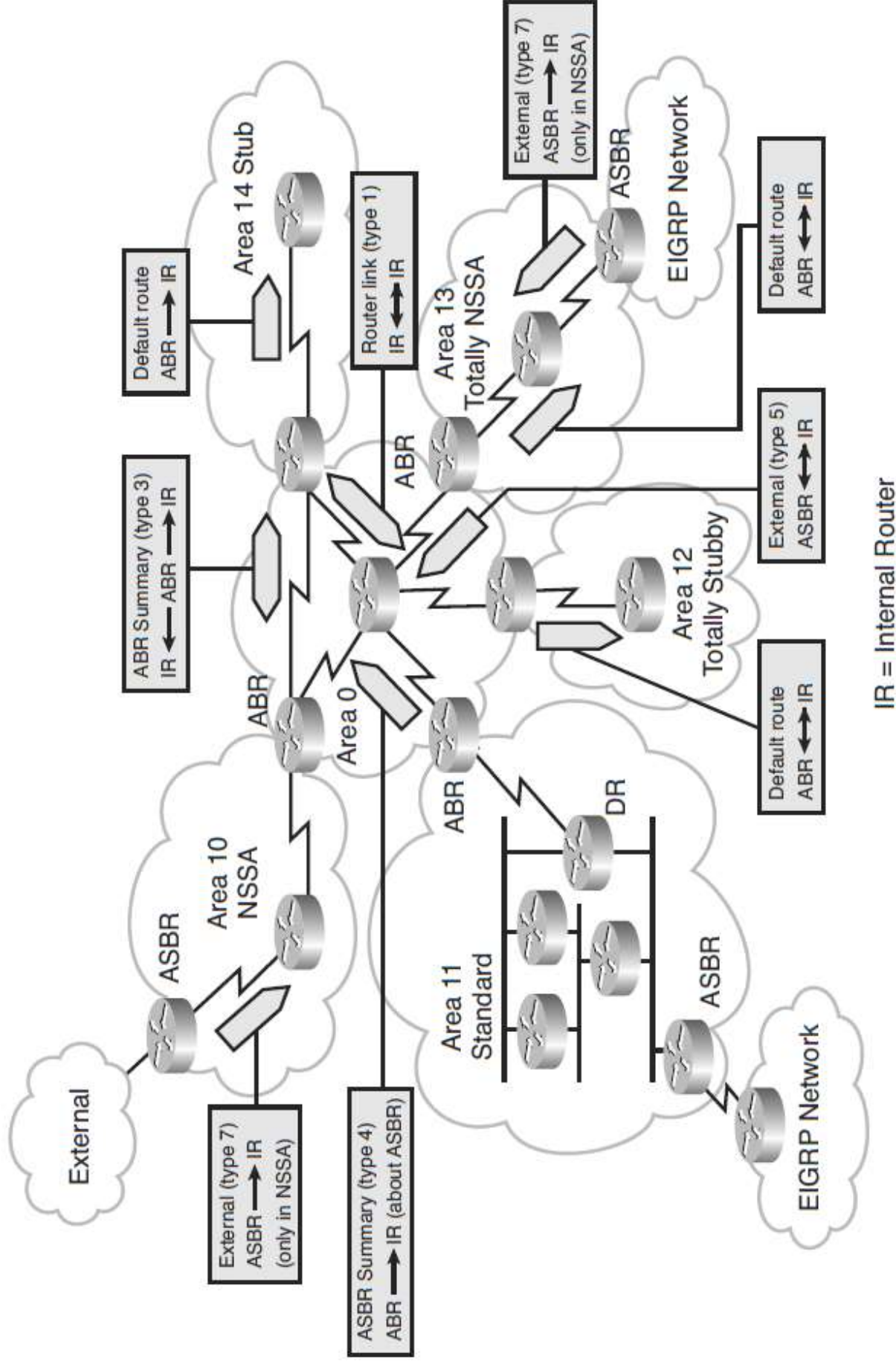
```
R1(config)# router ospf 10
R1(config-router)# redistribute rip subnets
R1(config-router)# default metric 150
R1(config-router)# network 172.17.0.0 0.0.255.255 area 1
R1(config-router)# area 1 nssa
R1(config-router)#
```

```
R2(config)# router ospf 10
R2(config-router)# summary-address 172.16.0.0 255.255.0.0
R2(config-router)# network 172.17.20.0 0.0.0.255 area 1
R2(config-router)# network 172.17.0.0 0.0.255.255 area 0
R2(config-router)# area 1 nssa no-summary
R2(config-router)#
```

How Does OSPF Generate Default Routes?

- Depends on the type of area.
- In a standard area:
 - Routers do not automatically generate default routes.
 - The `default-information originate` command must be used.
- In a stub and totally stubby area:
 - The ABR automatically generates a summary LSA with the link-state ID 0.0.0.0.
 - The `default-information originate` command is not required.
 - This is true even if the ABR does not have a default route.
- In an NSSA area:
 - The ABR generates the default route, but not by default.
 - To force the ABR to generate the default route, use the `area area-id nssa default-information-originate` command.
- In a totally stubby NSSA:
 - The ABR automatically generates a default route.

Example OSPF Area Types in a Network

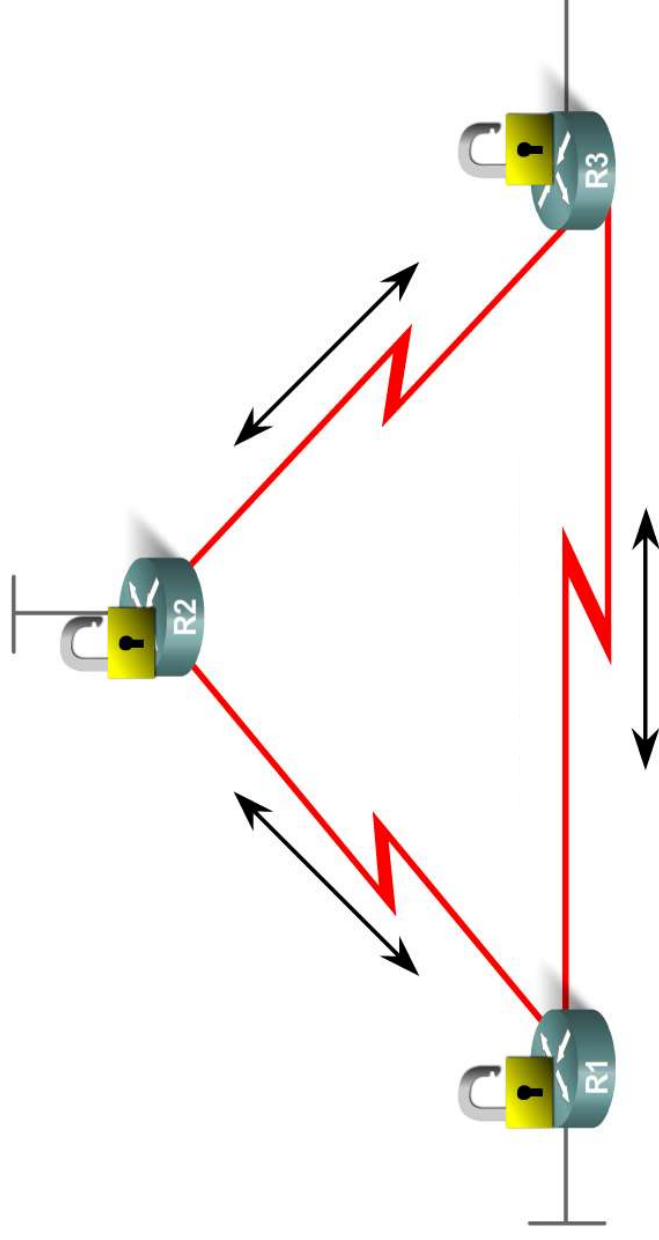


Configuring and Verifying Advanced OSPF Authentication

OSPF Authentication

- Purpose is to authenticate routing information.
- This is an interface specific configuration.
- Routers will only accept routing information from other routers that have been configured with the same authentication information.

Authentication



OSPF Authentication Types

- Router generates and checks each packet and authenticates the source of each update packet it receives
- Requires a pre-defined “key” (password)
 - Note: All participating neighbors must have the same key configured
- OSPF supports 2 types of authentication:
 - Simple password authentication (plain text)
 - Less secure
 - MD5 authentication
 - More secure and recommended

Planning for OSPF

- The following key parameters must be defined in enough detail before configuring OSPF authentication:
 - The authentication mode (simple password versus MD5)
 - The definition of one or more keys to authenticate OSPF packets, according to the network security plan.
- Once defined, the following steps may be implemented:
 1. Assign a password (key) to be used.
 - The actual command varies depending on the authentication mode used.
 2. Specify the authentication mode (simple password or MD5).

Configure A Key for Simple Authentication

- Define a password to use for simple password authentication.

```
Router(config-if) #
```

```
ip ospf authentication-key password
```

- The *password* parameter can be entered up to 8 bytes in length.
- This command is used in conjunction with the **ip ospf authentication** command.

Configure the MD5 Key-ID and Key

- Define a password to use for MD5 authentication.

```
Router(config-if) #
```

```
ip ospf message-digest-key key-id md5 key
```

- The *key-id* parameter is an identifier in the range from 1 to 255.
- The *key* parameter can be entered up to 16 bytes in length.
- All neighboring routers on the same network must have the same *key-id* and the same *key* value.
- This command is used in conjunction with the **ip ospf authentication message-digest** command.

Configure the Authentication Mode for OSPF

- Specify the authentication type.

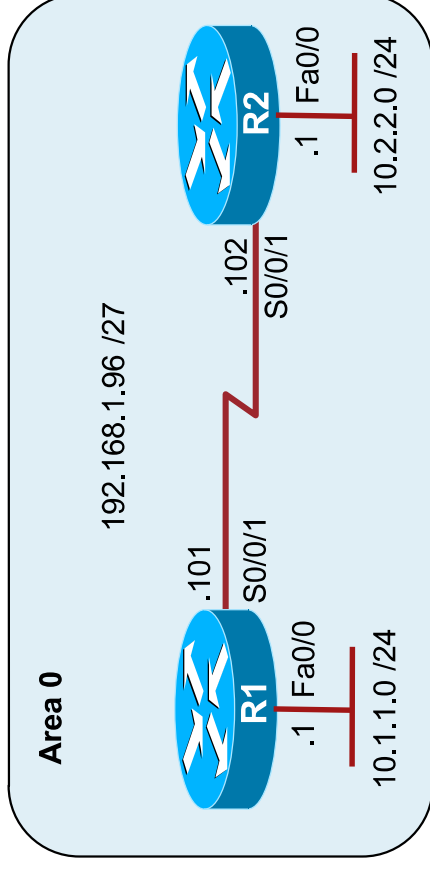
```
Router(config-if) #
```

```
ip ospf authentication [message-digest | null]
```

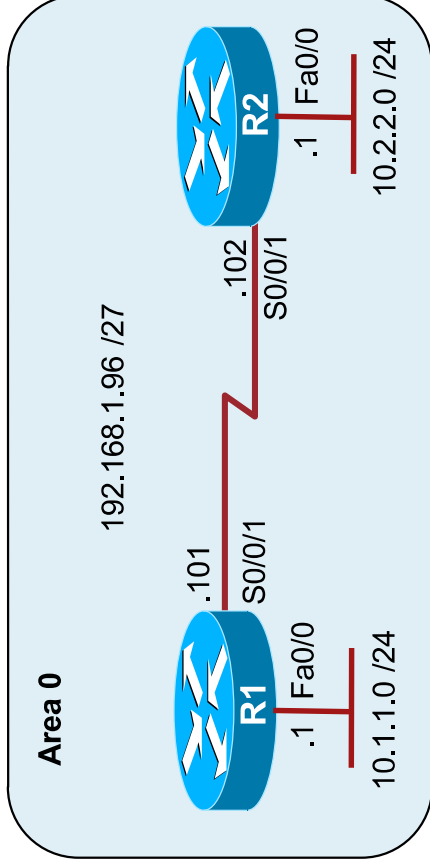
- Before using this command, configure a password.
- The command without any parameters specifies that simple password authentication will be used.
- The **message-digest** parameter specifies that MD5 authentication will be used.
- The **null** parameter specifies that no authentication is used.
 - This can be useful for overriding simple password or MD5 authentication.

Configuring Simple Password Authentication

```
R1# show running-config
!
<output omitted>
!
interface Fa0/0
ip address 10.1.1.1 255.255.255.0
!
<output omitted>
!
interface Serial0/0/1
ip address 192.168.1.101 255.255.255.224
ip ospf authentication
ip ospf authentication-key PLAINPAS
!
<output omitted>
!
router ospf 10
log-adjacency-changes
network 10.1.1.1 0.0.0.0 area 0
network 192.168.1.0 0.0.0.0 area 0
!
<output omitted>
```



Configuring Simple Password Authentication



```
R2# show running-config
!
<output omitted>
!
interface Fa0/0
ip address 10.2.2.1 255.255.255.0
!
<output omitted>
!
interface Serial0/0/1
ip address 192.168.1.102 255.255.255.224
ip ospf authentication
ip ospf authentication-key PLAINPAS
!
<output omitted>
!
router ospf 10
log-adjacency-changes
network 10.2.2.1 0.0.0.0 area 0
network 192.168.1.0 0.0.0.255 area 0
!
<output omitted>
```

Verifying Simple Password Authentication

Displays adjacency-related events of a successful connection.

```
R1# debug ip ospf adj
OSPF adjacency events debugging is on
R1#
<output omitted>
*Feb 17 18:42:01.250: OSPF: 2 Way Communication to 10.2.2.1 on Serial0/0/1,
state 2WAY
*Feb 17 18:42:01.250: OSPF: Send DBD to 10.2.2.1 on Serial0/0/1 seq 0x9B6 opt
0x52 flag 0x7 len 32
*Feb 17 18:42:01.262: OSPF: Rcv DBD from 10.2.2.1 on Serial0/0/1 seq 0x23ED
opt0x52 flag 0x7 len 32 mtu 1500 state EXSTART
*Feb 17 18:42:01.262: OSPF: NBR Negotiation Done. We are the SLAVE
*Feb 17 18:42:01.262: OSPF: Send DBD to 10.2.2.1 on Serial0/0/1 seq 0x23ED opt
0x52 flag 0x2 len 72
<output omitted>

R1# show ip ospf neighbor
Neighbor ID      Pri   State           Dead Time   Address      Interface
10.2.2.1         0    FULL/ -          00:00:34   192.168.1.102  Serial0/0/1
```

Troubleshooting Simple Password Problems

- Simple authentication on R1, no authentication on R2:

R1#

```
*Feb 17 18:51:31.242: OSPF: Rcv pkt from 192.168.1.102, Serial0/0/1  
: Mismatch Authentication type. Input packet specified type 0, we  
use type 1
```

R2#

```
*Feb 17 18:50:43.046: OSPF: Rcv pkt from 192.168.1.101, Serial0/0/1  
: Mismatch Authentication type. Input packet specified type 1, we  
use type 0
```

Troubleshooting Simple Password Problems

- Simple authentication on R1 and R2, but different passwords.

R1#

*Feb 17 18:54:01.238: OSPF: Rcv pkt from 192.168.1.102, Serial0/0/1

: Mismatch Authentication Key - Clear Text

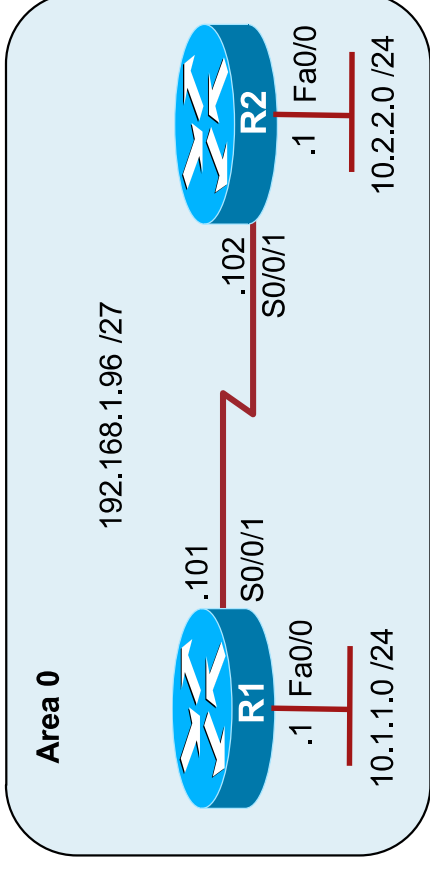
R2#

*Feb 17 18:53:13.050: OSPF: Rcv pkt from 192.168.1.101, Serial0/0/1

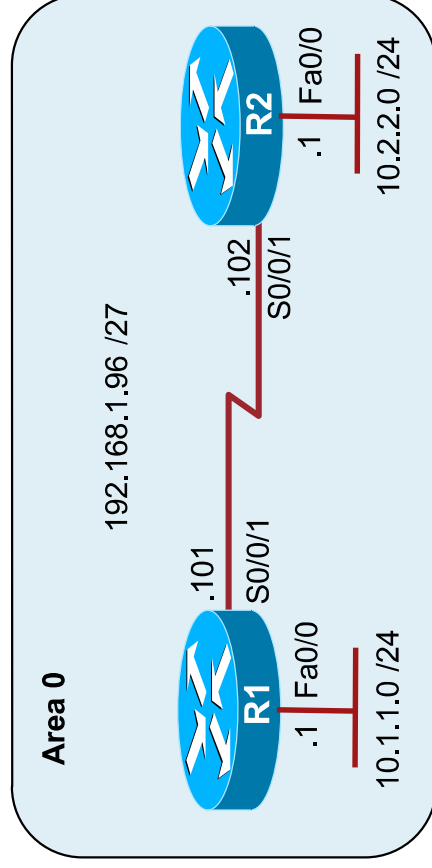
: Mismatch Authentication Key - Clear Text

Configuring MD5 Authentication

```
R1# show running-config
!
<output omitted>
!
interface Fa0/0
ip address 10.1.1.1 255.255.255.0
!
<output omitted>
!
interface Serial0/0/1
ip address 192.168.1.101 255.255.255.224
ip ospf authentication message-digest
ip ospf message-digest-key 1 md5 SECRETPASS
!
<output omitted>
!
router ospf 10
log-adjacency-changes
network 10.1.1.1 0.0.0.0 area 0
network 192.168.1.0 0.0.0.255 area 0
!
<output omitted>
```



Configuring MD5 Authentication



```
R2# show running-config
!
<output omitted>
!
interface Fa0/0
ip address 10.2.2.1 255.255.255.0
!
<output omitted>
!
interface Serial0/0/1
ip address 192.168.1.102 255.255.255.224
ip ospf authentication message-digest
ip ospf message-digest-key 1 md5 SECRETPASS
!
<output omitted>
!
router ospf 10
log-adjacency-changes
network 10.2.2.1 0.0.0.0 area 0
network 192.168.1.0 0.0.0.255 area 0
!
<output omitted>
```

Verifying MD5 Authentication

```
R1# show ip ospf interface
Serial0/0/1 is up, line protocol is up
Internet Address 192.168.1.101/27, Area 0
Process ID 10, Router ID 10.1.1.1, Network Type POINT_TO_POINT, Cost: 64
Transmit Delay is 1 sec, State POINT_TO_POINT
<output omitted>
Neighbor Count is 1, Adjacent neighbor count is 1
Adjacent with neighbor 10.2.2.1
Suppress hello for 0 neighbor(s)
Message digest authentication enabled
Youngest key id is 1
<output omitted>
R1#
R1# show ip ospf neighbor
Neighbor ID      Pri   State           Dead Time   Address      Interface
10.2.2.1         0    FULL/          00:00:31   192.168.1.102  Serial0/0/1
R1#
```

Verifying MD5 Authentication

```
R1# debug ip ospf adj
OSPF adjacency events debugging is on
<output omitted>
*Feb 17 17:14:06.530: OSPF: Send with youngest Key 1
*Feb 17 17:14:06.546: OSPF: 2 Way Communication to 10.2.2.2 on Serial0/0/1,
state 2WAY
*Feb 17 17:14:06.546: OSPF: Send DBD to 10.2.2.2 on Serial0/0/1 seq 0xB37 opt
0x52 flag 0x7 len 32
*Feb 17 17:14:06.546: OSPF: Send with youngest Key 1
*Feb 17 17:14:06.562: OSPF: Rcv DBD from 10.2.2.2 on Serial0/0/1 seq 0x32F
opt 0x52 flag 0x7 len 32 mtu 1500 state EXSTART
*Feb 17 17:14:06.562: OSPF: NBR Negotiation Done. We are the SLAVE
*Feb 17 17:14:06.562: OSPF: Send DBD to 10.2.2.2 on Serial0/0/1 seq 0x32F opt
0x52 flag 0x2 len 72
*Feb 17 17:14:06.562: OSPF: Send with youngest Key 1
<output omitted>
```

```
R1# show ip ospf neighbor
```

Neighbor ID	Pri	State	Dead Time	Address	Interface
10.2.2.2	0	FULL/	00:00:35	192.168.1.102	Serial0/0/1

Troubleshooting MD5 Authentication

MD5 authentication on both R1 and R2, but R1 has key 1 and R2 has key 2, both with the same passwords:

```
R1#
*Feb 17 17:56:16.530: OSPF: Send with youngest Key 1
*Feb 17 17:56:26.502: OSPF: Rcv pkt from 192.168.1.102, Serial0/0/1 : Mismatch
Authentication Key - No message digest key 2 on interface
*Feb 17 17:56:26.530: OSPF: Send with youngest Key 1

R2#
*Feb 17 17:55:28.226: OSPF: Send with youngest Key 2
*Feb 17 17:55:28.286: OSPF: Rcv pkt from 192.168.1.101, Serial0/0/1 : Mismatch
Authentication Key - No message digest key 1 on interface
*Feb 17 17:55:38.226: OSPF: Send with youngest Key 2
```

Configuring and Verifying Basic OSPF

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Ι. Ξυδάς