**Text

Description automatically generated**

**Purpose**

The network built demonstrates the usage of dynamic routing protocols OSPF (Open Shortest Path First) and OSPFv3 (an updated version of OSPF that uses IPv6 addressing) to route both IPv4 and IPv6 addresses. Multiple different OSPF areas, which are virtual groups that routers can join for the distribution of OSPF information, were configured to minimize the network overhead and load times for OSPF when dynamic routing changes are needed. These routing protocols simplify the routing process, allowing network administrators to type simple, robust commands to enable OSPF instead of manually configuring each route as well as allowing the network to expand without having to reconfigure existing routers.

**Background Information**

In this lab, the dynamic routing protocol OSPF’s configurations and operation were explored. The versions used in this lab were OSPFv2, meaning that it works with the familiar IPv4 addressing scheme, and OSPFv3, which uses IPv6 addressing. Both IPv4 and IPv6 addresses are used to give networks a virtual mailing address to be reached through.

The IPv4 addressing scheme works with a unique combination of 4 numbers from 0-255 (8 bits in binary) separated by dots in order to denote the IPv4 address. An example IPv4 address would be 192.168.0.1. However, different networks are separated from each other, and 4 simple numbers delimited by dots cannot identify what network the devices belong to. To accommodate this, the IPv4 addressing scheme uses a subnet mask to denote which part of the IPv4 address represents the network it belongs to, and which part of the address represents which host it is within that network. Since IPv4 addresses are binary based, the subnet mask separates network parts from host parts by denoting whether a certain bit belongs to the network or not. A sample subnet mask is 255.255.255.0, which donates that the first 3 numbers (24 bits) of the address belong to the network and the last number (8 bits) belongs to the host. Combined with the earlier 192.168.0.1 IPv4 address, the network address would be 192.168.0.0 and the host portion would be .1 within the network. This could also be written as 192.168.0.1/24 to show the IPv4 address and the subnet mask.

With that in mind, the first step of the OSPFv2 routing process is to make sure every router has a virtual mailing address for every connection it has. Every router represents the intersection between networks, so the router with 4 connections would be connected to 4 networks and would require 4 separate IPv4 addresses and subnet mask pairs. Afterwards, OSPFv2 is configured on every router to advertise every connection it has with other routers. The connected networks to be advertised are configured using the IPv4 address of the networks and a wildcard mask. The wildcard mask is the opposite of the subnet mask as when the subnet mask shows which part of the IPv4 address is the network address, the wildcard mask shows which parts are the host portion. For the earlier sample of the subnet mask, the 255.255.255.0 has the counterpart wildcard mask of 0.0.0.255, effectively flipping the binary bits.

The configuration used creates two areas of OSPF. Areas are the domain in which the routers can advertise their routing information between. By limiting the scope of advertisement of routing information within separate areas, the routers will handle less advertisement from all routers. Suppose there was a network with 100 routers. Every router would then have to handle information for all 100 routers once there is a single update to any router if they were on the same area. However, splitting up the 100 routers into separate areas makes it so that they do not have to constantly update information from other areas. As such, creating separate areas is beneficial for computing efficiency and the next step is to connect the areas together so that although they will limit the broadcasting scope of OSPF advertisements, OSPF advertisements are still able to cross different areas. Area 0 is the backbone area and must exist in all OSPF configurations. All areas must be connected to area 0 as it works as a hub or a bridge between multiple areas. As a result, Area Border Routers (ABRs) are configured to connect two separate areas and pass OSPF advertisements from one area to another. They are configured to have one connection in one area, and another in the next. In this lab, two areas were configured, area 0, the backbone area, and area 1. The Area Border Router would be connected to both the OSPF area 0 and area 1 to pass OSPF advertisements across.

After configuring OSPFv2, other routers receive this network information and now know how to reach certain networks through other learned routers through IPv4 addressing. All routers having to advertise at the same time can flood the networks and routers with information, so OSPF implements a system to select a single router to facilitate all the distribution of information. This router acts as a middleman between other routers. OSPF also implements a backup router to perform this task if this single middleman router fails to be connected. Passive interfaces are another feature that limits the amount of distribution of OSPF information. Passive interfaces are networks that are advertised to other routers but will not have advertisements sent to. It is essentially an outbox without an inbox. This is useful when there is a local area network without any routers to receive routing information, thus making any routing information sent into the network unusable. However, the existence of the network should still be advertised so that other routers know how to reach this local area network.

Once all router information is shared between all connected OSPFv2 enabled routers, they run Dijkstra’s shortest path algorithm to find the fastest way to reach all advertised networks. The shortest path is determined by the bandwidths from the source to destination, making a connection with 10 Mb/s have a higher cost than one with 1000 Mb/s. The shortest path to all advertised networks is stored in the router through a routing table and will be used to make forwarding decisions when receiving data to be transmitted.

OSPFv3 configuration is similar, but it uses the IPv6 addressing scheme. Because IPv4 addresses are only 32 bits long, there are constraints on the number of unique addresses available. IPv4 provides about 4 billion unique addresses, a number that is well within the scope of being all used up. Thus, IPv6 addressing was introduced, a 128-bit long address which has an astronomically larger address space. This helped solve the depletion of unique IPv4 addresses. They are represented in hexadecimal, meaning every digit represents a number from 0 to 15 as it is a base 16 number system. Groups of 4 hexadecimal digits are separated by colons and each represent 16 bits of the 128 bit-long address. If a group of hexadecimal digits does not have 4 digits, then there are leading 0s in that group of digits. A shorthand used in IPv6 addressing is using double colons in order to denote that until the next group of 4 hexadecimal digits, everything in between are all zeros. The last part of an IPv6 address is the network prefix, which signals how many of the 128 bits are used to distinguish the network portion and the host portion, like the subnet mask. By typical convention, the network portion would be 64 bits long and the host portion would be 64 bits long. A sample IPv6 address is 2001:0db8:acad:000a:0000:0000:0000:00ef/64. Notice that there are groups of 4 digits, and that there are the letters a, b, c, d, e, and f. These represents decimal 10, 11, 12, 13, 14, and 15 respectively. The slash followed by 64 signals the network prefix is 64 bits, meaning that the first 4 groups separated by colons belong to the network portion and the last 4 groups are used to identify hosts within that network. Using the shorthand mentioned before, this address can be shortened to 2001:db8:acad:a::ef/64. All the leading 0s of each group of 4 have been omitted and the long chain of 0s were replaced with a double colon. This keeps IPv6 addresses cleaner and shorter while still having the flexibility and access to the full 128-bit address-space.

With IPv6 addresses in mind, OSPFv3 configuration follows a very similar process to the configuration for OSPFv2. Every single connection on every network was given an IPv6 address. Then, OSPFv3 was enabled by configuring every connection to be part of the OSPFv2 process and given either an area number of 0 or area number of 1, just like OSPFv2. The difference in configuration was that in OSPFv2, network addresses and wildcard masks were used to activate a network for OSPF on that router. Instead, individual links are configured instead of networks, meaning the connected links to the routers are activated instead of the network the link is connected to. Fundamentally, with each link being configured with a valid IPv6 address and network prefix, the router can figure out which network the link is connected to, and that network will be advertised. With these configurations, IPv6 OSPFv3 has been configured and will simplify the routing process.

**Lab Summary**

5 routers were connected to each other in a straight-line using copper cross-over cables. Gigabit ethernet interfaces were used for all router connections. Every router was configured to accommodate dual-stack IPv4 and IPv6 addressing, routing, and connectivity. IPv4 addresses with /30 network subnet masks were used to accommodate networks between routers requiring only 2 network addresses. IPv6 global addresses and link-local addresses were both statically configured on all active interfaces of the routers. One loopback address per router was also configured with IPv4 addresses, IPv6 global, and IPv6 link-local addresses in order to simulate a connected LAN to the router. They were configured as passive interfaces, meaning that the loopback networks will be advertised to other routers, but that routing information is not sent towards the loopbacks. OSPFv2 and OSPFv3 were used to create dynamic routes between the routers. The process-id used for all configurations was 10 and two areas were used, area 0 and area 1. One router in the middle serves as a bridge between the two areas (Area Border Router). Router 3 and router 4 were configured to have the hello interval changed to 20 seconds instead of the default 10 seconds, and the dead interval was automatically adjusted to 4 times the hello interval, increasing up to 80 seconds.

**Lab Commands**

**Router (config) # router ospf <process-id>**

Enables OSPF on the router and enters OSPF configuration mode. The process-id is significant to the router itself only and helps to distinguish one OSPF configuration from another.

**Router# show ip ospf route**

Shows all learned routes through OSPF and the costs to get to each network. Includes the area number, process ID, interfaces activated in OSPF, and networks configured locally on the router.

**Router# show ip protocols**

Shows all the configured IP protocols on the router, including OSPF’s configured area number, process ID, administrative distance, reference bandwidth, and passive-interfaces.

**Router# show ip ospf neighbor**

Shows all connected and adjacent OSPF enabled routers, including the connected interfaces, the IP addresses, OSPF link-state, and the OSPF hello and dead timers used for maintaining adjacencies.

**Router# show ip ospf database**

Shows the OSPF topology table, which includes router ID and other information about all OSPF enabled routers in the area.

**Router (config-router) # network <network-address> <wildcard mask> area <number>**

Enables the specified network for OSPF advertisement. The network address is the IPv4 address of a specified network, and the wildcard mask is the inverse of the subnet mask. For example, the corresponding wildcard mask of the subnet mask 255.255.255.0 would be 0.0.0.255 as it would be flipping every binary bit in the subnet mask. The area number specifies the group of routers OSPF can be advertised within. When working with single-area OSPF, area 0 must be used.

**Router (config-if) #ip ospf <process-id> area <area number>**

Enables the specified interface for OSPF advertisement. The process-id is significant to the router itself and helps to distinguish separate OSPF configurations. The area number specifies the group of routers OSPF can be advertised within. When working with single-area OSPF, area 0 must be used.

**Router# clear ip ospf process**

Restarts the OSPF processes without having to reload the entire router. Clearing the OSPF processes is used to reset any faulty or premature elections of the Designated and Backup Designated Router as it restarts the entire election process.

**Router (config-router) # auto-cost reference-bandwidth <bandwidth in Mb/s>**

Sets the reference bandwidth used to calculate the cost of traversing a link. The bandwidth is measured in megabits per second and the cost of a link, if not manually configured, is calculated through dividing the reference bandwidth with the link’s maximum bandwidth. The default reference bandwidth is 10 megabits per second. Calculations are rounded up, so if a gigabit ethernet port (1000 megabits per second) was assigned a cost through the default reference bandwidth, 10 / 1000 rounds up to 1. It is good practice to set the reference bandwidth to be the maximum bandwidth of the largest link.

**Router (config-if) # ip ospf cost <cost of link>**

Manually sets the cost to traverse a link. Cost is used to determine the shortest path through an OSPF enabled network of routers.

**Router (config) # router ospfv3 <process-id>**

Enters global OSPFv3 configuration mode. It is a similar command to the **router ospf <process-id>** command for OSPFv2. It includes configurations for OSPFv3 areas, reference bandwidths, and passive interfaces. The process-id is significant for the router itself to distinguish between different OSPFv3 configurations.

**Router (config-if) # ipv6 ospf <process-id> area <area number>**

Enables the specific interface to be advertised over the OSPFv3 network. The process-id is significant for the router itself to distinguish between different OSPFv3 configurations. The area number is used to determine the group of routers which OSPFv3 information can be distributed across.

**Router# show ipv6 ospf route**

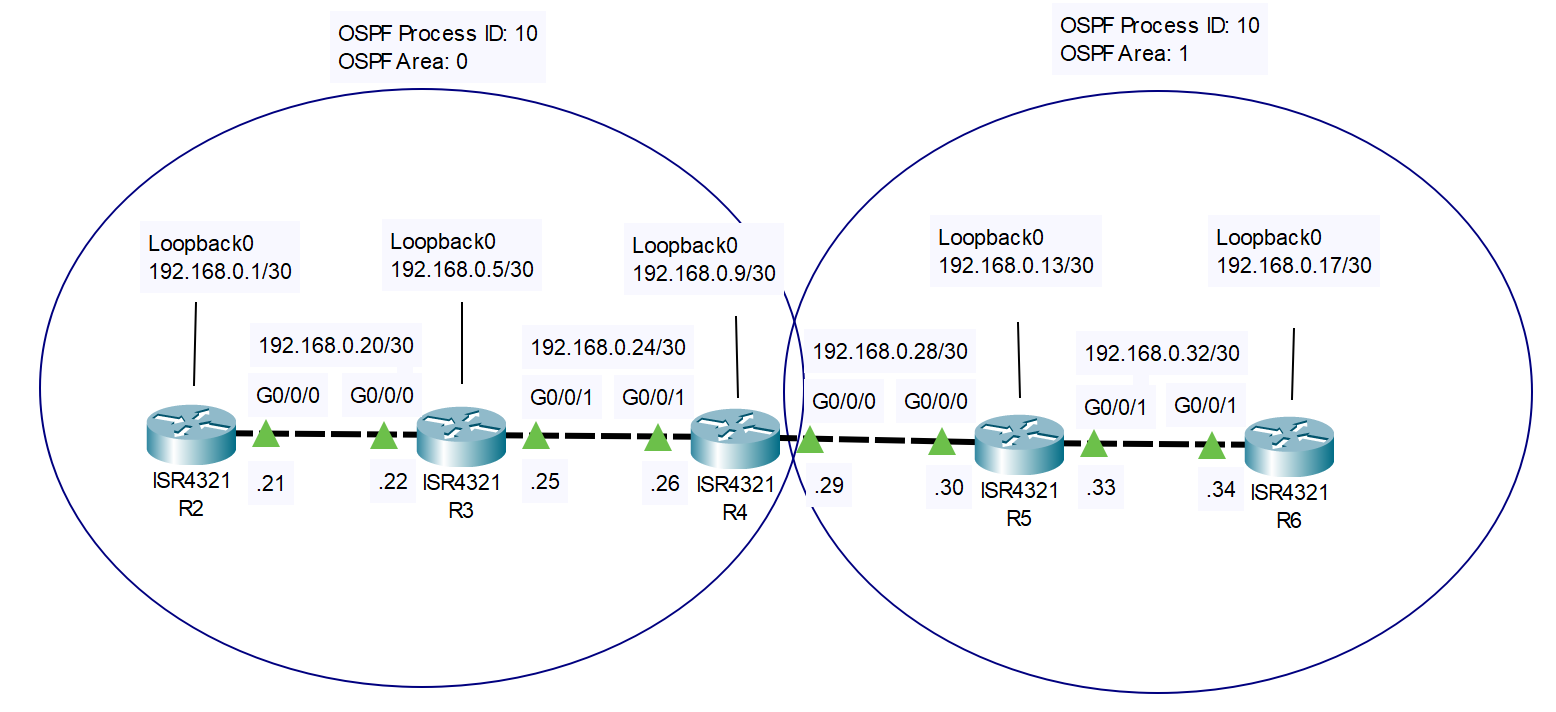
Shows all learned routes through OSPFv3 and the costs to get to each network. Includes the area number, process ID, interfaces activated in OSPFv3, and networks configured locally on the router.

**Router# show ipv6 protocols**

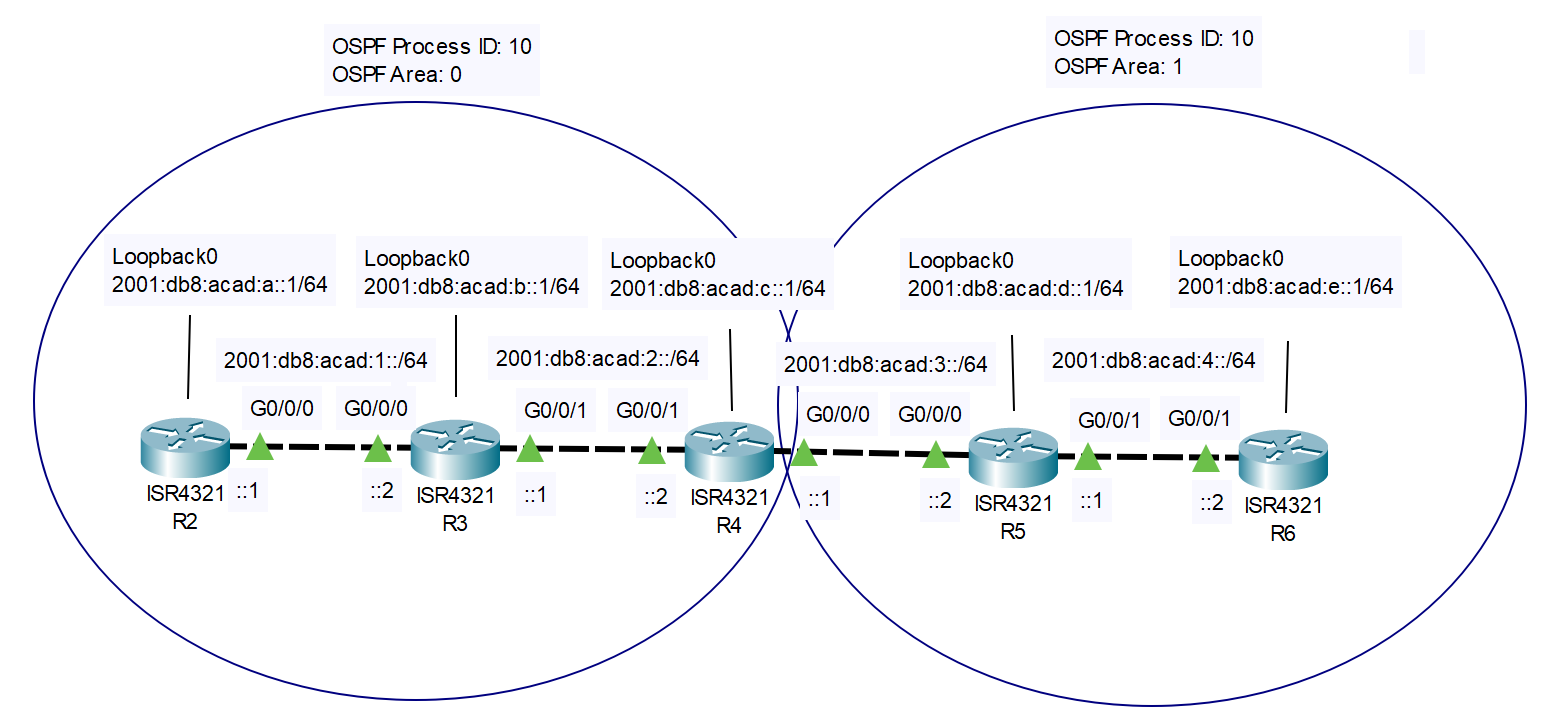
Shows all the configured IPv6 protocols on the router, including OSPF’s configured area number, process ID, administrative distance, reference bandwidth, and passive-interfaces.

**Network Diagram with IP’s**

**IPv4**



**IPv6**



|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Router Name** | Interface | IP Address | IPv6 Global Address | IPv6 Link-Local Address |
| **R2** | G0/0/0 | 192.168.0.21/30 | 2001:db8:acad:1::1/64 | fe80::11/10 |
|  | G0/0/1 | N/A | N/A | N/A |
|  | Loopback0 | 192.168.0.1/30 | 2001:db8:acad:a::1/64 | fe80::1/10 |
|  |  |  |  |  |
| **R3** | G0/0/0 | 192.168.0.22/30 | 2001:db8:acad:1::2/64 | fe80::12/10 |
|  | G0/0/1 | 192.168.0.25/30 | 2001:db8:acad:2::1/64 | fe80::21/10 |
|  | Loopback0 | 192.168.0.5/30 | 2001:db8:acad:b::1/64 | fe80::1/10 |
|  |  |  |  |  |
| **R4** | G0/0/0 | 192.168.0.29/30 | 2001:db8:acad:3::1/64 | fe80::31/10 |
|  | G0/0/1 | 192.168.0.26/30 | 2001:db8:acad:2::2/64 | fe80::22/10 |
|  | Loopback0 | 192.168.0.9/30 | 2001:db8:acad:c::1/64 | fe80::1/10 |
|  |  |  |  |  |
| **R5** | G0/0/0 | 192.168.0.30/30 | 2001:db8:acad:3::2/64 | fe80::32/10 |
|  | G0/0/1 | 192.168.0.33/30 | 2001:db8:acad:4::1/64 | fe80::41/10 |
|  | Loopback0 | 192.168.0.13/30 | 2001:db8:acad:d::1/64 | fe80::1/10 |
|  |  |  |  |  |
| **R6** | G0/0/0 | N/A | N/A | N/A |
|  | G0/0/1 | 192.168.0.34/30 | 2001:db8:acad:4::2/64 | fe80::42/10 |
|  | Loopback0 | 192.168.0.17/30 | 2001:db8:acad:e::1/64 | fe80::1/10 |

**Configurations**

**Router 2**

**R2#show running-config**

Current configuration : 4024 bytes

version 15.5

service timestamps debug datetime msec

service timestamps log datetime msec

no platform punt-keepalive disable-kernel-core

hostname R2

boot-start-marker

boot-end-marker

vrf definition Mgmt-intf

address-family ipv4

exit-address-family

address-family ipv6

exit-address-family

no aaa new-model

ip dhcp pool webuidhcp

ipv6 unicast-routing

subscriber templating

multilink bundle-name authenticated

crypto pki trustpoint TP-self-signed-2219300048

enrollment selfsigned

subject-name cn=IOS-Self-Signed-Certificate-2219300048

revocation-check none

rsakeypair TP-self-signed-2219300048

crypto pki certificate chain TP-self-signed-2219300048

certificate self-signed 01

30820330 30820218 A0030201 02020101 300D0609 2A864886 F70D0101 05050030

31312F30 2D060355 04031326 494F532D 53656C66 2D536967 6E65642D 43657274

69666963 6174652D 32323139 33303030 3438301E 170D3231 30393230 31343533

35315A17 0D333030 31303130 30303030 305A3031 312F302D 06035504 03132649

4F532D53 656C662D 5369676E 65642D43 65727469 66696361 74652D32 32313933

30303034 38308201 22300D06 092A8648 86F70D01 01010500 0382010F 00308201

0A028201 0100A82A 86792E00 AAAD3E06 1A405132 383AA68B 5C6058BA 32549353

1ABE9D11 A08788FB 9EE12E1A DAC6AEB5 D506E76D 49D7B893 F5C3281F E238C21C

DF165F33 43337CE8 5C490289 89F32FF8 9E8F5F9D 61934C26 E19CB7FF 3BE54375

A9DCEB33 731E58CD BCD3EE04 8B261BA3 2D4B9843 A3920AC0 6BFCE4B8 B34E3EC3

0A7DC8FD E56EEDA1 2D14D5A5 0920CACA 71CC8EA6 A60D1CD1 F5AD2D92 CEE0BE5E

B6B75FC3 329370FD 91D495DC EA00C200 53B0016D 9DCEAC69 8D436DE1 926F581C

F3464B20 50903398 DAD45947 3399EFF5 F099A0EF 3B1023C4 99F3373C 9B9FFB3D

169882E4 7C6EC0D5 E4C9AE59 C9E8A1BD A5F8C286 078170F8 37ED177D EE846C1E

42B34E11 909F0203 010001A3 53305130 0F060355 1D130101 FF040530 030101FF

301F0603 551D2304 18301680 142FBA05 1A8A9B59 6C0E245C C27537BA F4CF0494

FC301D06 03551D0E 04160414 2FBA051A 8A9B596C 0E245CC2 7537BAF4 CF0494FC

300D0609 2A864886 F70D0101 05050003 82010100 0833FFFB 512EB41F 9D0FCF96

F28947FE 21E9BADC CCAE1C67 392511B7 DDA37303 8EF49750 9EC14ED6 E51B93F5

9ADA664E 1065CD05 041B8E4D A6689AAB EAED38CB 7939859F BA72F8D0 7DABB321

FDD0DF22 0DF5029C 897DB1D0 ABCAC467 184618D4 0C9BA788 083F349D DC01BD02

E42AF81E 3778DF86 08A4D9F0 83E0AA19 7C66AAD6 E346165B D62ECA57 B5DC8567

D1A7A304 8DCEFC6F 8BECC50C 387E8481 5DF5C306 32833911 D67CBF48 9B4AE20C

0CC8B0E5 84A3DE1F 19B0B613 FD2614D5 9177948D 9218B9A9 1734909D 2C51627C

D743D09A 73C2DAD2 BCB4E88D D3E8EBB9 1E5285E4 3E079658 84EDAC5C AF432464

995B159D C6981A35 A4CA3281 5E7ABCA8 C703BF3D

quit

license udi pid ISR4321/K9 sn FDO214421BY

spanning-tree extend system-id

redundancy

mode none

vlan internal allocation policy ascending

interface Loopback0

ip address 192.168.0.1 255.255.255.252

ipv6 address FE80::1 link-local

ipv6 address 2001:DB8:ACAD:A::1/64

ipv6 ospf 10 area 0

interface GigabitEthernet0/0/0

ip address 192.168.0.21 255.255.255.252

negotiation auto

ipv6 address FE80::11 link-local

ipv6 address 2001:DB8:ACAD:1::1/64

ipv6 ospf 10 area 0

interface GigabitEthernet0/0/1

no ip address

negotiation auto

interface Serial0/1/0

no ip address

shutdown

interface Serial0/1/1

no ip address

shutdown

interface GigabitEthernet0/2/0

no ip address

shutdown

negotiation auto

interface GigabitEthernet0/2/1

no ip address

shutdown

negotiation auto

interface GigabitEthernet0

vrf forwarding Mgmt-intf

no ip address

shutdown

negotiation auto

interface Vlan1

no ip address

shutdown

router ospf 10

network 192.168.0.0 0.0.0.3 area 0

network 192.168.0.20 0.0.0.3 area 0

ip forward-protocol nd

no ip http server

no ip http secure-server

ip tftp source-interface GigabitEthernet0

ipv6 router ospf 10

control-plane

line con 0

stopbits 1

line aux 0

stopbits 1

line vty 0 4

login

end

**R2#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

a - application route

+ - replicated route, % - next hop override, p - overrides from PfR

Gateway of last resort is not set

192.168.0.0/24 is variably subnetted, 11 subnets, 2 masks

C 192.168.0.0/30 is directly connected, Loopback0

L 192.168.0.1/32 is directly connected, Loopback0

O 192.168.0.5/32

[110/2] via 192.168.0.22, 00:10:40, GigabitEthernet0/0/0

O 192.168.0.9/32

[110/3] via 192.168.0.22, 00:10:40, GigabitEthernet0/0/0

O IA 192.168.0.13/32

[110/4] via 192.168.0.22, 00:10:40, GigabitEthernet0/0/0

O IA 192.168.0.17/32

[110/5] via 192.168.0.22, 00:10:40, GigabitEthernet0/0/0

C 192.168.0.20/30 is directly connected, GigabitEthernet0/0/0

L 192.168.0.21/32 is directly connected, GigabitEthernet0/0/0

O 192.168.0.24/30

[110/2] via 192.168.0.22, 00:10:40, GigabitEthernet0/0/0

O IA 192.168.0.28/30

[110/3] via 192.168.0.22, 00:10:40, GigabitEthernet0/0/0

O IA 192.168.0.32/30

[110/4] via 192.168.0.22, 00:10:40, GigabitEthernet0/0/0

**R2#show ip ospf route**

OSPF Router with ID (192.168.0.1) (Process ID 10)

Base Topology (MTID 0)

Area BACKBONE(0)

Intra-area Route List

\* 192.168.0.20/30, Intra, cost 1, area 0, Connected

via 192.168.0.21, GigabitEthernet0/0/0

\*> 192.168.0.24/30, Intra, cost 2, area 0

via 192.168.0.22, GigabitEthernet0/0/0

\* 192.168.0.1/32, Intra, cost 1, area 0, Connected

via 192.168.0.1, Loopback0

\*> 192.168.0.5/32, Intra, cost 2, area 0

via 192.168.0.22, GigabitEthernet0/0/0

\*> 192.168.0.9/32, Intra, cost 3, area 0

via 192.168.0.22, GigabitEthernet0/0/0

Inter-area Route List

\*> 192.168.0.28/30, Inter, cost 3, area 0

via 192.168.0.22, GigabitEthernet0/0/0

\*> 192.168.0.32/30, Inter, cost 4, area 0

via 192.168.0.22, GigabitEthernet0/0/0

\*> 192.168.0.13/32, Inter, cost 4, area 0

via 192.168.0.22, GigabitEthernet0/0/0

\*> 192.168.0.17/32, Inter, cost 5, area 0

via 192.168.0.22, GigabitEthernet0/0/0

Intra-area Router Path List

i 192.168.0.9 [2] via 192.168.0.22, GigabitEthernet0/0/0, ABR, Area 0, SPF 2

First Hop Forwarding Gateway Tree

192.168.0.21 on GigabitEthernet0/0/0, count 1

192.168.0.22 on GigabitEthernet0/0/0, count 7

192.168.0.1 on Loopback0, count 1

**R2#show ip protocols**

\*\*\* IP Routing is NSF aware \*\*\*

Routing Protocol is "application"

Sending updates every 0 seconds

Invalid after 0 seconds, hold down 0, flushed after 0

Outgoing update filter list for all interfaces is not set

Incoming update filter list for all interfaces is not set

Maximum path: 32

Routing for Networks:

Routing Information Sources:

Gateway Distance Last Update

Distance: (default is 4)

Routing Protocol is "ospf 10"

Outgoing update filter list for all interfaces is not set

Incoming update filter list for all interfaces is not set

Router ID 192.168.0.1

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

Maximum path: 4

Routing for Networks:

192.168.0.0 0.0.0.3 area 0

192.168.0.20 0.0.0.3 area 0

Routing Information Sources:

Gateway Distance Last Update

192.168.0.9 110 00:10:51

192.168.0.5 110 00:10:51

Distance: (default is 110)

**R2#show ipv6 route**

IPv6 Routing Table - default - 12 entries

Codes: C - Connected, L - Local, S - Static, U - Per-user Static route

B - BGP, R - RIP, I1 - ISIS L1, I2 - ISIS L2

IA - ISIS interarea, IS - ISIS summary, D - EIGRP, EX - EIGRP external

ND - ND Default, NDp - ND Prefix, DCE - Destination, NDr - Redirect

O - OSPF Intra, OI - OSPF Inter, OE1 - OSPF ext 1, OE2 - OSPF ext 2

ON1 - OSPF NSSA ext 1, ON2 - OSPF NSSA ext 2, a - Application

C 2001:DB8:ACAD:1::/64 [0/0]

via GigabitEthernet0/0/0, directly connected

L 2001:DB8:ACAD:1::1/128 [0/0]

via GigabitEthernet0/0/0, receive

O 2001:DB8:ACAD:2::/64 [110/2]

via FE80::12, GigabitEthernet0/0/0

OI 2001:DB8:ACAD:3::/64 [110/3]

via FE80::12, GigabitEthernet0/0/0

OI 2001:DB8:ACAD:4::/64 [110/4]

via FE80::12, GigabitEthernet0/0/0

C 2001:DB8:ACAD:A::/64 [0/0]

via Loopback0, directly connected

L 2001:DB8:ACAD:A::1/128 [0/0]

via Loopback0, receive

O 2001:DB8:ACAD:B::1/128 [110/1]

via FE80::12, GigabitEthernet0/0/0

O 2001:DB8:ACAD:C::1/128 [110/2]

via FE80::12, GigabitEthernet0/0/0

OI 2001:DB8:ACAD:D::1/128 [110/3]

via FE80::12, GigabitEthernet0/0/0

OI 2001:DB8:ACAD:E::1/128 [110/4]

via FE80::12, GigabitEthernet0/0/0

L FF00::/8 [0/0]

via Null0, receive

**R2#show ipv6 ospf route**

OSPFv3 Router with ID (192.168.0.1) (Process ID 10)

Area BACKBONE(0)

Intra-area Route List

\* 2001:DB8:ACAD:1::/64, Intra, cost 1, area 0, Connected

via GigabitEthernet0/0/0

\*> 2001:DB8:ACAD:2::/64, Intra, cost 2, area 0

via FE80::12, GigabitEthernet0/0/0

\* 2001:DB8:ACAD:A::1/128, Intra, cost 0, area 0, Connected

via Null0

\*> 2001:DB8:ACAD:B::1/128, Intra, cost 1, area 0

via FE80::12, GigabitEthernet0/0/0

\*> 2001:DB8:ACAD:C::1/128, Intra, cost 2, area 0

via FE80::12, GigabitEthernet0/0/0

Inter-area Route List

\*> 2001:DB8:ACAD:3::/64, Inter, cost 3, area 0

via FE80::12, GigabitEthernet0/0/0

\*> 2001:DB8:ACAD:4::/64, Inter, cost 4, area 0

via FE80::12, GigabitEthernet0/0/0

\*> 2001:DB8:ACAD:D::1/128, Inter, cost 3, area 0

via FE80::12, GigabitEthernet0/0/0

\*> 2001:DB8:ACAD:E::1/128, Inter, cost 4, area 0

via FE80::12, GigabitEthernet0/0/0

First Hop Forwarding Gateway Tree

:: on Null0, count 1

:: on GigabitEthernet0/0/0, count 1

FE80::12 on GigabitEthernet0/0/0, count 7

**R2#show ipv6 protocols**

IPv6 Routing Protocol is "connected"

IPv6 Routing Protocol is "application"

IPv6 Routing Protocol is "ND"

IPv6 Routing Protocol is "ospf 10"

Router ID 192.168.0.1

Number of areas: 1 normal, 0 stub, 0 nssa

Interfaces (Area 0):

Loopback0

GigabitEthernet0/0/0

Redistribution:

None

**Router 3**

**R3#show running-config**

Current configuration : 1947 bytes

version 15.5

service timestamps debug datetime msec

service timestamps log datetime msec

no platform punt-keepalive disable-kernel-core

hostname R3

boot-start-marker

boot-end-marker

vrf definition Mgmt-intf

address-family ipv4

exit-address-family

address-family ipv6

exit-address-family

no aaa new-model

ipv6 unicast-routing

subscriber templating

multilink bundle-name authenticated

license udi pid ISR4321/K9 sn FDO214421BY

spanning-tree extend system-id

redundancy

mode none

vlan internal allocation policy ascending

interface Loopback0

ip address 192.168.0.5 255.255.255.252

ip ospf 10 area 0

ipv6 address FE80::1 link-local

ipv6 address 2001:DB8:ACAD:B::1/64

ipv6 ospf 10 area 0

interface GigabitEthernet0/0/0

ip address 192.168.0.22 255.255.255.252

ip ospf 10 area 0

negotiation auto

ipv6 address FE80::12 link-local

ipv6 address 2001:DB8:ACAD:1::2/64

ipv6 ospf 10 area 0

interface GigabitEthernet0/0/1

ip address 192.168.0.25 255.255.255.252

ip ospf hello-interval 20

ip ospf 10 area 0

negotiation auto

ipv6 address FE80::21 link-local

ipv6 address 2001:DB8:ACAD:2::1/64

ipv6 ospf 10 area 0

interface Serial0/1/0

no ip address

shutdown

interface Serial0/1/1

no ip address

shutdown

interface GigabitEthernet0/2/0

no ip address

shutdown

negotiation auto

interface GigabitEthernet0/2/1

no ip address

shutdown

negotiation auto

interface GigabitEthernet0

vrf forwarding Mgmt-intf

no ip address

shutdown

negotiation auto

interface Vlan1

no ip address

shutdown

router ospfv3 10

address-family ipv6 unicast

exit-address-family

router ospf 10

passive-interface Loopback0

ip forward-protocol nd

no ip http server

no ip http secure-server

ip tftp source-interface GigabitEthernet0

control-plane

line con 0

stopbits 1

line aux 0

stopbits 1

line vty 0 4

login

end

**R3#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

a - application route

+ - replicated route, % - next hop override, p - overrides from PfR

Gateway of last resort is not set

192.168.0.0/24 is variably subnetted, 12 subnets, 2 masks

O 192.168.0.1/32

[110/2] via 192.168.0.21, 00:12:18, GigabitEthernet0/0/0

C 192.168.0.4/30 is directly connected, Loopback0

L 192.168.0.5/32 is directly connected, Loopback0

O 192.168.0.9/32

[110/2] via 192.168.0.26, 00:48:01, GigabitEthernet0/0/1

O IA 192.168.0.13/32

[110/3] via 192.168.0.26, 00:47:31, GigabitEthernet0/0/1

O IA 192.168.0.17/32

[110/4] via 192.168.0.26, 00:47:21, GigabitEthernet0/0/1

C 192.168.0.20/30 is directly connected, GigabitEthernet0/0/0

L 192.168.0.22/32 is directly connected, GigabitEthernet0/0/0

C 192.168.0.24/30 is directly connected, GigabitEthernet0/0/1

L 192.168.0.25/32 is directly connected, GigabitEthernet0/0/1

O IA 192.168.0.28/30

[110/2] via 192.168.0.26, 00:48:01, GigabitEthernet0/0/1

O IA 192.168.0.32/30

[110/3] via 192.168.0.26, 00:47:31, GigabitEthernet0/0/1

**R3#show ip ospf route**

OSPF Router with ID (192.168.0.5) (Process ID 10)

Base Topology (MTID 0)

Area BACKBONE(0)

Intra-area Route List

\* 192.168.0.20/30, Intra, cost 1, area 0, Connected

via 192.168.0.22, GigabitEthernet0/0/0

\* 192.168.0.24/30, Intra, cost 1, area 0, Connected

via 192.168.0.25, GigabitEthernet0/0/1

\*> 192.168.0.1/32, Intra, cost 2, area 0

via 192.168.0.21, GigabitEthernet0/0/0

\* 192.168.0.5/32, Intra, cost 1, area 0, Connected

via 192.168.0.5, Loopback0

\*> 192.168.0.9/32, Intra, cost 2, area 0

via 192.168.0.26, GigabitEthernet0/0/1

Inter-area Route List

\*> 192.168.0.28/30, Inter, cost 2, area 0

via 192.168.0.26, GigabitEthernet0/0/1

\*> 192.168.0.32/30, Inter, cost 3, area 0

via 192.168.0.26, GigabitEthernet0/0/1

\*> 192.168.0.13/32, Inter, cost 3, area 0

via 192.168.0.26, GigabitEthernet0/0/1

\*> 192.168.0.17/32, Inter, cost 4, area 0

via 192.168.0.26, GigabitEthernet0/0/1

Intra-area Router Path List

i 192.168.0.9 [1] via 192.168.0.26, GigabitEthernet0/0/1, ABR, Area 0, SPF 10

First Hop Forwarding Gateway Tree

192.168.0.21 on GigabitEthernet0/0/0, count 1

192.168.0.22 on GigabitEthernet0/0/0, count 1

192.168.0.25 on GigabitEthernet0/0/1, count 1

192.168.0.26 on GigabitEthernet0/0/1, count 5

192.168.0.5 on Loopback0, count 1

**R3#show ip protocols**

\*\*\* IP Routing is NSF aware \*\*\*

Routing Protocol is "application"

Sending updates every 0 seconds

Invalid after 0 seconds, hold down 0, flushed after 0

Outgoing update filter list for all interfaces is not set

Incoming update filter list for all interfaces is not set

Maximum path: 32

Routing for Networks:

Routing Information Sources:

Gateway Distance Last Update

Distance: (default is 4)

Routing Protocol is "ospf 10"

Outgoing update filter list for all interfaces is not set

Incoming update filter list for all interfaces is not set

Router ID 192.168.0.5

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

Maximum path: 4

Routing for Networks:

Routing on Interfaces Configured Explicitly (Area 0):

Loopback0

GigabitEthernet0/0/0

GigabitEthernet0/0/1

Passive Interface(s):

Loopback0

Routing Information Sources:

Gateway Distance Last Update

192.168.0.9 110 00:47:30

192.168.0.1 110 00:12:27

Distance: (default is 110)

**R3#show ipv6 route**

IPv6 Routing Table - default - 13 entries

Codes: C - Connected, L - Local, S - Static, U - Per-user Static route

B - BGP, R - RIP, I1 - ISIS L1, I2 - ISIS L2

IA - ISIS interarea, IS - ISIS summary, D - EIGRP, EX - EIGRP external

ND - ND Default, NDp - ND Prefix, DCE - Destination, NDr - Redirect

O - OSPF Intra, OI - OSPF Inter, OE1 - OSPF ext 1, OE2 - OSPF ext 2

ON1 - OSPF NSSA ext 1, ON2 - OSPF NSSA ext 2, a - Application

C 2001:DB8:ACAD:1::/64 [0/0]

via GigabitEthernet0/0/0, directly connected

L 2001:DB8:ACAD:1::2/128 [0/0]

via GigabitEthernet0/0/0, receive

C 2001:DB8:ACAD:2::/64 [0/0]

via GigabitEthernet0/0/1, directly connected

L 2001:DB8:ACAD:2::1/128 [0/0]

via GigabitEthernet0/0/1, receive

OI 2001:DB8:ACAD:3::/64 [110/2]

via FE80::22, GigabitEthernet0/0/1

OI 2001:DB8:ACAD:4::/64 [110/3]

via FE80::22, GigabitEthernet0/0/1

O 2001:DB8:ACAD:A::1/128 [110/1]

via FE80::11, GigabitEthernet0/0/0

C 2001:DB8:ACAD:B::/64 [0/0]

via Loopback0, directly connected

L 2001:DB8:ACAD:B::1/128 [0/0]

via Loopback0, receive

O 2001:DB8:ACAD:C::1/128 [110/1]

via FE80::22, GigabitEthernet0/0/1

OI 2001:DB8:ACAD:D::1/128 [110/2]

via FE80::22, GigabitEthernet0/0/1

OI 2001:DB8:ACAD:E::1/128 [110/3]

via FE80::22, GigabitEthernet0/0/1

L FF00::/8 [0/0]

via Null0, receive

**R3#show ipv6 ospf route**

OSPFv3 Router with ID (192.168.0.5) (Process ID 10)

Area BACKBONE(0)

Intra-area Route List

\* 2001:DB8:ACAD:1::/64, Intra, cost 1, area 0, Connected

via GigabitEthernet0/0/0

\* 2001:DB8:ACAD:2::/64, Intra, cost 1, area 0, Connected

via GigabitEthernet0/0/1

\*> 2001:DB8:ACAD:A::1/128, Intra, cost 1, area 0

via FE80::11, GigabitEthernet0/0/0

\* 2001:DB8:ACAD:B::1/128, Intra, cost 0, area 0, Connected

via Null0

\*> 2001:DB8:ACAD:C::1/128, Intra, cost 1, area 0

via FE80::22, GigabitEthernet0/0/1

Inter-area Route List

\*> 2001:DB8:ACAD:3::/64, Inter, cost 2, area 0

via FE80::22, GigabitEthernet0/0/1

\*> 2001:DB8:ACAD:4::/64, Inter, cost 3, area 0

via FE80::22, GigabitEthernet0/0/1

\*> 2001:DB8:ACAD:D::1/128, Inter, cost 2, area 0

via FE80::22, GigabitEthernet0/0/1

\*> 2001:DB8:ACAD:E::1/128, Inter, cost 3, area 0

via FE80::22, GigabitEthernet0/0/1

First Hop Forwarding Gateway Tree

:: on Null0, count 1

:: on GigabitEthernet0/0/0, count 1

FE80::11 on GigabitEthernet0/0/0, count 1

:: on GigabitEthernet0/0/1, count 1

FE80::22 on GigabitEthernet0/0/1, count 5

**R3#show ipv6 protocols**

IPv6 Routing Protocol is "connected"

IPv6 Routing Protocol is "application"

IPv6 Routing Protocol is "ND"

IPv6 Routing Protocol is "ospf 10"

Router ID 192.168.0.5

Number of areas: 1 normal, 0 stub, 0 nssa

Interfaces (Area 0):

Loopback0

GigabitEthernet0/0/1

GigabitEthernet0/0/0

Redistribution:

None

**Router 4**

**R4#show running-config**

Current configuration : 2000 bytes

version 15.5

service timestamps debug datetime msec

service timestamps log datetime msec

no platform punt-keepalive disable-kernel-core

hostname R4

boot-start-marker

boot-end-marker

vrf definition Mgmt-intf

address-family ipv4

exit-address-family

address-family ipv6

exit-address-family

no aaa new-model

ipv6 unicast-routing

subscriber templating

multilink bundle-name authenticated

license udi pid ISR4321/K9 sn FDO214913GF

spanning-tree extend system-id

redundancy

mode none

vlan internal allocation policy ascending

interface Loopback0

ip address 192.168.0.9 255.255.255.252

ipv6 address FE80::1 link-local

ipv6 address 2001:DB8:ACAD:C::1/64

ipv6 ospf 10 area 0

interface GigabitEthernet0/0/0

ip address 192.168.0.29 255.255.255.252

negotiation auto

ipv6 address FE80::31 link-local

ipv6 address 2001:DB8:ACAD:3::1/64

ipv6 ospf 10 area 1

interface GigabitEthernet0/0/1

ip address 192.168.0.26 255.255.255.252

ip ospf hello-interval 20

negotiation auto

ipv6 address FE80::22 link-local

ipv6 address 2001:DB8:ACAD:2::2/64

ipv6 ospf 10 area 0

interface Serial0/1/0

no ip address

shutdown

interface Serial0/1/1

no ip address

shutdown

interface GigabitEthernet0/2/0

no ip address

shutdown

negotiation auto

interface GigabitEthernet0/2/1

no ip address

shutdown

negotiation auto

interface GigabitEthernet0

vrf forwarding Mgmt-intf

no ip address

shutdown

negotiation auto

interface Vlan1

no ip address

shutdown

router ospfv3 10

address-family ipv6 unicast

exit-address-family

router ospf 10

passive-interface Loopback0

network 192.168.0.8 0.0.0.3 area 0

network 192.168.0.24 0.0.0.3 area 0

network 192.168.0.28 0.0.0.3 area 1

ip forward-protocol nd

no ip http server

no ip http secure-server

ip tftp source-interface GigabitEthernet0

control-plane

line con 0

stopbits 1

line aux 0

stopbits 1

line vty 0 4

login

end

**R4#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

a - application route

+ - replicated route, % - next hop override, p - overrides from PfR

Gateway of last resort is not set

192.168.0.0/24 is variably subnetted, 12 subnets, 2 masks

O 192.168.0.1/32

[110/3] via 192.168.0.25, 00:15:18, GigabitEthernet0/0/1

O 192.168.0.5/32

[110/2] via 192.168.0.25, 00:51:00, GigabitEthernet0/0/1

C 192.168.0.8/30 is directly connected, Loopback0

L 192.168.0.9/32 is directly connected, Loopback0

O 192.168.0.13/32

[110/2] via 192.168.0.30, 00:50:31, GigabitEthernet0/0/0

O 192.168.0.17/32

[110/3] via 192.168.0.30, 00:50:21, GigabitEthernet0/0/0

O 192.168.0.20/30

[110/2] via 192.168.0.25, 00:26:44, GigabitEthernet0/0/1

C 192.168.0.24/30 is directly connected, GigabitEthernet0/0/1

L 192.168.0.26/32 is directly connected, GigabitEthernet0/0/1

C 192.168.0.28/30 is directly connected, GigabitEthernet0/0/0

L 192.168.0.29/32 is directly connected, GigabitEthernet0/0/0

O 192.168.0.32/30

[110/2] via 192.168.0.30, 00:50:21, GigabitEthernet0/0/0

**R4#show ip ospf route**

OSPF Router with ID (192.168.0.9) (Process ID 10)

Base Topology (MTID 0)

Area BACKBONE(0)

Intra-area Route List

\* 192.168.0.24/30, Intra, cost 1, area 0, Connected

via 192.168.0.26, GigabitEthernet0/0/1

\*> 192.168.0.20/30, Intra, cost 2, area 0

via 192.168.0.25, GigabitEthernet0/0/1

\*> 192.168.0.1/32, Intra, cost 3, area 0

via 192.168.0.25, GigabitEthernet0/0/1

\*> 192.168.0.5/32, Intra, cost 2, area 0

via 192.168.0.25, GigabitEthernet0/0/1

\* 192.168.0.9/32, Intra, cost 1, area 0, Connected

via 192.168.0.9, Loopback0

Area 1

Intra-area Route List

\* 192.168.0.28/30, Intra, cost 1, area 1, Connected

via 192.168.0.29, GigabitEthernet0/0/0

\*> 192.168.0.32/30, Intra, cost 2, area 1

via 192.168.0.30, GigabitEthernet0/0/0

\*> 192.168.0.13/32, Intra, cost 2, area 1

via 192.168.0.30, GigabitEthernet0/0/0

\*> 192.168.0.17/32, Intra, cost 3, area 1

via 192.168.0.30, GigabitEthernet0/0/0

First Hop Forwarding Gateway Tree

192.168.0.9 on Loopback0, count 1

192.168.0.29 on GigabitEthernet0/0/0, count 1

192.168.0.30 on GigabitEthernet0/0/0, count 3

192.168.0.25 on GigabitEthernet0/0/1, count 3

192.168.0.26 on GigabitEthernet0/0/1, count 1

**R4#show ip protocols**

\*\*\* IP Routing is NSF aware \*\*\*

Routing Protocol is "application"

Sending updates every 0 seconds

Invalid after 0 seconds, hold down 0, flushed after 0

Outgoing update filter list for all interfaces is not set

Incoming update filter list for all interfaces is not set

Maximum path: 32

Routing for Networks:

Routing Information Sources:

Gateway Distance Last Update

Distance: (default is 4)

Routing Protocol is "ospf 10"

Outgoing update filter list for all interfaces is not set

Incoming update filter list for all interfaces is not set

Router ID 192.168.0.9

It is an area border router

Number of areas in this router is 2. 2 normal 0 stub 0 nssa

Maximum path: 4

Routing for Networks:

192.168.0.8 0.0.0.3 area 0

192.168.0.24 0.0.0.3 area 0

192.168.0.28 0.0.0.3 area 1

Passive Interface(s):

Loopback0

Routing Information Sources:

Gateway Distance Last Update

192.168.0.13 110 00:50:40

192.168.0.1 110 00:15:27

192.168.0.5 110 00:26:53

192.168.0.17 110 00:50:30

Distance: (default is 110)

**R4#show ipv6 route**

IPv6 Routing Table - default - 13 entries

Codes: C - Connected, L - Local, S - Static, U - Per-user Static route

B - BGP, R - RIP, I1 - ISIS L1, I2 - ISIS L2

IA - ISIS interarea, IS - ISIS summary, D - EIGRP, EX - EIGRP external

ND - ND Default, NDp - ND Prefix, DCE - Destination, NDr - Redirect

O - OSPF Intra, OI - OSPF Inter, OE1 - OSPF ext 1, OE2 - OSPF ext 2

ON1 - OSPF NSSA ext 1, ON2 - OSPF NSSA ext 2, a - Application

O 2001:DB8:ACAD:1::/64 [110/2]

via FE80::21, GigabitEthernet0/0/1

C 2001:DB8:ACAD:2::/64 [0/0]

via GigabitEthernet0/0/1, directly connected

L 2001:DB8:ACAD:2::2/128 [0/0]

via GigabitEthernet0/0/1, receive

C 2001:DB8:ACAD:3::/64 [0/0]

via GigabitEthernet0/0/0, directly connected

L 2001:DB8:ACAD:3::1/128 [0/0]

via GigabitEthernet0/0/0, receive

O 2001:DB8:ACAD:4::/64 [110/2]

via FE80::32, GigabitEthernet0/0/0

O 2001:DB8:ACAD:A::1/128 [110/2]

via FE80::21, GigabitEthernet0/0/1

O 2001:DB8:ACAD:B::1/128 [110/1]

via FE80::21, GigabitEthernet0/0/1

C 2001:DB8:ACAD:C::/64 [0/0]

via Loopback0, directly connected

L 2001:DB8:ACAD:C::1/128 [0/0]

via Loopback0, receive

O 2001:DB8:ACAD:D::1/128 [110/1]

via FE80::32, GigabitEthernet0/0/0

O 2001:DB8:ACAD:E::1/128 [110/2]

via FE80::32, GigabitEthernet0/0/0

L FF00::/8 [0/0]

via Null0, receive

**R4#show ipv6 ospf route**

OSPFv3 Router with ID (192.168.0.9) (Process ID 10)

Area BACKBONE(0)

Intra-area Route List

\*> 2001:DB8:ACAD:1::/64, Intra, cost 2, area 0

via FE80::21, GigabitEthernet0/0/1

\* 2001:DB8:ACAD:2::/64, Intra, cost 1, area 0, Connected

via GigabitEthernet0/0/1

\*> 2001:DB8:ACAD:A::1/128, Intra, cost 2, area 0

via FE80::21, GigabitEthernet0/0/1

\*> 2001:DB8:ACAD:B::1/128, Intra, cost 1, area 0

via FE80::21, GigabitEthernet0/0/1

\* 2001:DB8:ACAD:C::1/128, Intra, cost 0, area 0, Connected

via Null0

Area 1

Intra-area Route List

\* 2001:DB8:ACAD:3::/64, Intra, cost 1, area 1, Connected

via GigabitEthernet0/0/0

\*> 2001:DB8:ACAD:4::/64, Intra, cost 2, area 1

via FE80::32, GigabitEthernet0/0/0

\*> 2001:DB8:ACAD:D::1/128, Intra, cost 1, area 1

via FE80::32, GigabitEthernet0/0/0

\*> 2001:DB8:ACAD:E::1/128, Intra, cost 2, area 1

via FE80::32, GigabitEthernet0/0/0

First Hop Forwarding Gateway Tree

:: on Null0, count 1

:: on GigabitEthernet0/0/0, count 1

FE80::32 on GigabitEthernet0/0/0, count 3

:: on GigabitEthernet0/0/1, count 1

FE80::21 on GigabitEthernet0/0/1, count 3

**R4#show ipv6 protocols**

IPv6 Routing Protocol is "connected"

IPv6 Routing Protocol is "application"

IPv6 Routing Protocol is "ND"

IPv6 Routing Protocol is "ospf 10"

Router ID 192.168.0.9

Area border router

Number of areas: 2 normal, 0 stub, 0 nssa

Interfaces (Area 0):

Loopback0

GigabitEthernet0/0/1

Interfaces (Area 1):

GigabitEthernet0/0/0

Redistribution:

None

**Router 5**

**R5#show running-config**

Current configuration : 1948 bytes

version 15.5

service timestamps debug datetime msec

service timestamps log datetime msec

no platform punt-keepalive disable-kernel-core

hostname R5

boot-start-marker

boot-end-marker

vrf definition Mgmt-intf

address-family ipv4

exit-address-family

address-family ipv6

exit-address-family

no aaa new-model

ipv6 unicast-routing

subscriber templating

multilink bundle-name authenticated

license udi pid ISR4321/K9 sn FDO21482HYV

spanning-tree extend system-id

redundancy

mode none

vlan internal allocation policy ascending

interface Loopback0

ip address 192.168.0.13 255.255.255.252

ip ospf 10 area 1

ipv6 address FE80::1 link-local

ipv6 address 2001:DB8:ACAD:D::1/64

ipv6 ospf 10 area 1

interface GigabitEthernet0/0/0

ip address 192.168.0.30 255.255.255.252

ip ospf 10 area 1

negotiation auto

ipv6 address FE80::32 link-local

ipv6 address 2001:DB8:ACAD:3::2/64

ipv6 ospf 10 area 1

interface GigabitEthernet0/0/1

ip address 192.168.0.33 255.255.255.252

ip ospf 10 area 1

negotiation auto

ipv6 address FE80::41 link-local

ipv6 address 2001:DB8:ACAD:4::1/64

ipv6 ospf 10 area 1

interface Serial0/1/0

no ip address

shutdown

interface Serial0/1/1

no ip address

shutdown

interface GigabitEthernet0/2/0

no ip address

shutdown

negotiation auto

interface GigabitEthernet0/2/1

no ip address

shutdown

negotiation auto

interface GigabitEthernet0

vrf forwarding Mgmt-intf

no ip address

shutdown

negotiation auto

interface Vlan1

no ip address

shutdown

router ospfv3 10

address-family ipv6 unicast

exit-address-family

router ospf 10

passive-interface Loopback0

ip forward-protocol nd

no ip http server

no ip http secure-server

ip tftp source-interface GigabitEthernet0

control-plane

line con 0

stopbits 1

line aux 0

stopbits 1

line vty 0 4

login

end

**R5#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

a - application route

+ - replicated route, % - next hop override, p - overrides from PfR

Gateway of last resort is not set

192.168.0.0/24 is variably subnetted, 12 subnets, 2 masks

O IA 192.168.0.1/32

[110/4] via 192.168.0.29, 00:15:05, GigabitEthernet0/0/0

O IA 192.168.0.5/32

[110/3] via 192.168.0.29, 00:50:18, GigabitEthernet0/0/0

O IA 192.168.0.9/32

[110/2] via 192.168.0.29, 00:50:18, GigabitEthernet0/0/0

C 192.168.0.12/30 is directly connected, Loopback0

L 192.168.0.13/32 is directly connected, Loopback0

O 192.168.0.17/32

[110/2] via 192.168.0.34, 00:50:08, GigabitEthernet0/0/1

O IA 192.168.0.20/30

[110/3] via 192.168.0.29, 00:26:31, GigabitEthernet0/0/0

O IA 192.168.0.24/30

[110/2] via 192.168.0.29, 00:50:18, GigabitEthernet0/0/0

C 192.168.0.28/30 is directly connected, GigabitEthernet0/0/0

L 192.168.0.30/32 is directly connected, GigabitEthernet0/0/0

C 192.168.0.32/30 is directly connected, GigabitEthernet0/0/1

L 192.168.0.33/32 is directly connected, GigabitEthernet0/0/1

**R5#show ip ospf route**

OSPF Router with ID (192.168.0.13) (Process ID 10)

Base Topology (MTID 0)

Area 1

Intra-area Route List

\* 192.168.0.28/30, Intra, cost 1, area 1, Connected

via 192.168.0.30, GigabitEthernet0/0/0

\* 192.168.0.32/30, Intra, cost 1, area 1, Connected

via 192.168.0.33, GigabitEthernet0/0/1

\* 192.168.0.13/32, Intra, cost 1, area 1, Connected

via 192.168.0.13, Loopback0

\*> 192.168.0.17/32, Intra, cost 2, area 1

via 192.168.0.34, GigabitEthernet0/0/1

Inter-area Route List

\*> 192.168.0.1/32, Inter, cost 4, area 1

via 192.168.0.29, GigabitEthernet0/0/0

\*> 192.168.0.20/30, Inter, cost 3, area 1

via 192.168.0.29, GigabitEthernet0/0/0

\*> 192.168.0.24/30, Inter, cost 2, area 1

via 192.168.0.29, GigabitEthernet0/0/0

\*> 192.168.0.5/32, Inter, cost 3, area 1

via 192.168.0.29, GigabitEthernet0/0/0

\*> 192.168.0.9/32, Inter, cost 2, area 1

via 192.168.0.29, GigabitEthernet0/0/0

Intra-area Router Path List

i 192.168.0.9 [1] via 192.168.0.29, GigabitEthernet0/0/0, ABR, Area 1, SPF 4

First Hop Forwarding Gateway Tree

192.168.0.29 on GigabitEthernet0/0/0, count 5

192.168.0.30 on GigabitEthernet0/0/0, count 1

192.168.0.33 on GigabitEthernet0/0/1, count 1

192.168.0.34 on GigabitEthernet0/0/1, count 1

192.168.0.13 on Loopback0, count 1

**R5#show ip protocols**

\*\*\* IP Routing is NSF aware \*\*\*

Routing Protocol is "application"

Sending updates every 0 seconds

Invalid after 0 seconds, hold down 0, flushed after 0

Outgoing update filter list for all interfaces is not set

Incoming update filter list for all interfaces is not set

Maximum path: 32

Routing for Networks:

Routing Information Sources:

Gateway Distance Last Update

Distance: (default is 4)

Routing Protocol is "ospf 10"

Outgoing update filter list for all interfaces is not set

Incoming update filter list for all interfaces is not set

Router ID 192.168.0.13

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

Maximum path: 4

Routing for Networks:

Routing on Interfaces Configured Explicitly (Area 1):

Loopback0

GigabitEthernet0/0/0

GigabitEthernet0/0/1

Passive Interface(s):

Loopback0

Routing Information Sources:

Gateway Distance Last Update

192.168.0.9 110 00:15:18

192.168.0.17 110 00:50:21

Distance: (default is 110)

**R5#show ipv6 route**

IPv6 Routing Table - default - 13 entries

Codes: C - Connected, L - Local, S - Static, U - Per-user Static route

B - BGP, R - RIP, I1 - ISIS L1, I2 - ISIS L2

IA - ISIS interarea, IS - ISIS summary, D - EIGRP, EX - EIGRP external

ND - ND Default, NDp - ND Prefix, DCE - Destination, NDr - Redirect

O - OSPF Intra, OI - OSPF Inter, OE1 - OSPF ext 1, OE2 - OSPF ext 2

ON1 - OSPF NSSA ext 1, ON2 - OSPF NSSA ext 2, a - Application

OI 2001:DB8:ACAD:1::/64 [110/3]

via FE80::31, GigabitEthernet0/0/0

OI 2001:DB8:ACAD:2::/64 [110/2]

via FE80::31, GigabitEthernet0/0/0

C 2001:DB8:ACAD:3::/64 [0/0]

via GigabitEthernet0/0/0, directly connected

L 2001:DB8:ACAD:3::2/128 [0/0]

via GigabitEthernet0/0/0, receive

C 2001:DB8:ACAD:4::/64 [0/0]

via GigabitEthernet0/0/1, directly connected

L 2001:DB8:ACAD:4::1/128 [0/0]

via GigabitEthernet0/0/1, receive

OI 2001:DB8:ACAD:A::1/128 [110/3]

via FE80::31, GigabitEthernet0/0/0

OI 2001:DB8:ACAD:B::1/128 [110/2]

via FE80::31, GigabitEthernet0/0/0

OI 2001:DB8:ACAD:C::1/128 [110/1]

via FE80::31, GigabitEthernet0/0/0

C 2001:DB8:ACAD:D::/64 [0/0]

via Loopback0, directly connected

L 2001:DB8:ACAD:D::1/128 [0/0]

via Loopback0, receive

O 2001:DB8:ACAD:E::1/128 [110/1]

via FE80::42, GigabitEthernet0/0/1

L FF00::/8 [0/0]

via Null0, receive

**R5#show ipv6 ospf route**

OSPFv3 Router with ID (192.168.0.13) (Process ID 10)

Area 1

Intra-area Route List

\* 2001:DB8:ACAD:3::/64, Intra, cost 1, area 1, Connected

via GigabitEthernet0/0/0

\* 2001:DB8:ACAD:4::/64, Intra, cost 1, area 1, Connected

via GigabitEthernet0/0/1

\* 2001:DB8:ACAD:D::1/128, Intra, cost 0, area 1, Connected

via Null0

\*> 2001:DB8:ACAD:E::1/128, Intra, cost 1, area 1

via FE80::42, GigabitEthernet0/0/1

Inter-area Route List

\*> 2001:DB8:ACAD:A::1/128, Inter, cost 3, area 1

via FE80::31, GigabitEthernet0/0/0

\*> 2001:DB8:ACAD:1::/64, Inter, cost 3, area 1

via FE80::31, GigabitEthernet0/0/0

\*> 2001:DB8:ACAD:2::/64, Inter, cost 2, area 1

via FE80::31, GigabitEthernet0/0/0

\*> 2001:DB8:ACAD:C::1/128, Inter, cost 1, area 1

via FE80::31, GigabitEthernet0/0/0

\*> 2001:DB8:ACAD:B::1/128, Inter, cost 2, area 1

via FE80::31, GigabitEthernet0/0/0

First Hop Forwarding Gateway Tree

:: on Null0, count 1

:: on GigabitEthernet0/0/0, count 1

FE80::31 on GigabitEthernet0/0/0, count 5

:: on GigabitEthernet0/0/1, count 1

FE80::42 on GigabitEthernet0/0/1, count 1

**R5#show ipv6 protocols**

IPv6 Routing Protocol is "connected"

IPv6 Routing Protocol is "application"

IPv6 Routing Protocol is "ND"

IPv6 Routing Protocol is "ospf 10"

Router ID 192.168.0.13

Number of areas: 1 normal, 0 stub, 0 nssa

Interfaces (Area 1):

Loopback0

GigabitEthernet0/0/1

GigabitEthernet0/0/0

Redistribution:

None

**Router 6**

**R6#show running-config**

Current configuration : 1620 bytes

version 15.5

service timestamps debug datetime msec

service timestamps log datetime msec

no platform punt-keepalive disable-kernel-core

hostname R6

boot-start-marker

boot-end-marker

vrf definition Mgmt-intf

address-family ipv4

exit-address-family

address-family ipv6

exit-address-family

no aaa new-model

ipv6 unicast-routing

subscriber templating

multilink bundle-name authenticated

license udi pid ISR4321/K9 sn FDO214333H6

spanning-tree extend system-id

redundancy

mode none

vlan internal allocation policy ascending

interface Loopback0

ip address 192.168.0.17 255.255.255.252

ip ospf 10 area 1

ipv6 address FE80::1 link-local

ipv6 address 2001:DB8:ACAD:E::1/64

ipv6 ospf 10 area 1

interface GigabitEthernet0/0/0

no ip address

shutdown

negotiation auto

interface GigabitEthernet0/0/1

ip address 192.168.0.34 255.255.255.252

ip ospf 10 area 1

negotiation auto

ipv6 address FE80::42 link-local

ipv6 address 2001:DB8:ACAD:4::2/64

ipv6 ospf 10 area 1

interface Serial0/1/0

no ip address

shutdown

interface Serial0/1/1

no ip address

shutdown

interface GigabitEthernet0

vrf forwarding Mgmt-intf

no ip address

shutdown

negotiation auto

interface Vlan1

no ip address

shutdown

router ospf 10

ip forward-protocol nd

no ip http server

no ip http secure-server

ip tftp source-interface GigabitEthernet0

ipv6 router ospf 10

passive-interface Loopback0

control-plane

line con 0

stopbits 1

line aux 0

stopbits 1

line vty 0 4

login

end

**R6#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

a - application route

+ - replicated route, % - next hop override, p - overrides from PfR

Gateway of last resort is not set

192.168.0.0/24 is variably subnetted, 11 subnets, 2 masks

O IA 192.168.0.1/32

[110/5] via 192.168.0.33, 00:10:06, GigabitEthernet0/0/1

O IA 192.168.0.5/32

[110/4] via 192.168.0.33, 00:45:18, GigabitEthernet0/0/1

O IA 192.168.0.9/32

[110/3] via 192.168.0.33, 00:45:18, GigabitEthernet0/0/1

O 192.168.0.13/32

[110/2] via 192.168.0.33, 00:45:18, GigabitEthernet0/0/1

C 192.168.0.16/30 is directly connected, Loopback0

L 192.168.0.17/32 is directly connected, Loopback0

O IA 192.168.0.20/30

[110/4] via 192.168.0.33, 00:21:31, GigabitEthernet0/0/1

O IA 192.168.0.24/30

[110/3] via 192.168.0.33, 00:45:18, GigabitEthernet0/0/1

O 192.168.0.28/30

[110/2] via 192.168.0.33, 00:45:18, GigabitEthernet0/0/1

C 192.168.0.32/30 is directly connected, GigabitEthernet0/0/1

L 192.168.0.34/32 is directly connected, GigabitEthernet0/0/1

**R6#show ip ospf route**

OSPF Router with ID (192.168.0.17) (Process ID 10)

Base Topology (MTID 0)

Area 1

Intra-area Route List

\* 192.168.0.32/30, Intra, cost 1, area 1, Connected

via 192.168.0.34, GigabitEthernet0/0/1

\*> 192.168.0.28/30, Intra, cost 2, area 1

via 192.168.0.33, GigabitEthernet0/0/1

\*> 192.168.0.13/32, Intra, cost 2, area 1

via 192.168.0.33, GigabitEthernet0/0/1

\* 192.168.0.17/32, Intra, cost 1, area 1, Connected

via 192.168.0.17, Loopback0

Inter-area Route List

\*> 192.168.0.1/32, Inter, cost 5, area 1

via 192.168.0.33, GigabitEthernet0/0/1

\*> 192.168.0.20/30, Inter, cost 4, area 1

via 192.168.0.33, GigabitEthernet0/0/1

\*> 192.168.0.24/30, Inter, cost 3, area 1

via 192.168.0.33, GigabitEthernet0/0/1

\*> 192.168.0.5/32, Inter, cost 4, area 1

via 192.168.0.33, GigabitEthernet0/0/1

\*> 192.168.0.9/32, Inter, cost 3, area 1

via 192.168.0.33, GigabitEthernet0/0/1

Intra-area Router Path List

i 192.168.0.9 [2] via 192.168.0.33, GigabitEthernet0/0/1, ABR, Area 1, SPF 3

First Hop Forwarding Gateway Tree

192.168.0.33 on GigabitEthernet0/0/1, count 7

192.168.0.34 on GigabitEthernet0/0/1, count 1

192.168.0.17 on Loopback0, count 1

**R6#show ip protocols**

\*\*\* IP Routing is NSF aware \*\*\*

Routing Protocol is "application"

Sending updates every 0 seconds

Invalid after 0 seconds, hold down 0, flushed after 0

Outgoing update filter list for all interfaces is not set

Incoming update filter list for all interfaces is not set

Maximum path: 32

Routing for Networks:

Routing Information Sources:

Gateway Distance Last Update

Distance: (default is 4)

Routing Protocol is "ospf 10"

Outgoing update filter list for all interfaces is not set

Incoming update filter list for all interfaces is not set

Router ID 192.168.0.17

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

Maximum path: 4

Routing for Networks:

Routing on Interfaces Configured Explicitly (Area 1):

Loopback0

GigabitEthernet0/0/1

Passive Interface(s):

Loopback0

Routing Information Sources:

Gateway Distance Last Update

192.168.0.9 110 00:12:53

192.168.0.13 110 00:48:05

Distance: (default is 110)

**R6#show ipv6 route**

IPv6 Routing Table - default - 12 entries

Codes: C - Connected, L - Local, S - Static, U - Per-user Static route

B - BGP, R - RIP, I1 - ISIS L1, I2 - ISIS L2

IA - ISIS interarea, IS - ISIS summary, D - EIGRP, EX - EIGRP external

ND - ND Default, NDp - ND Prefix, DCE - Destination, NDr - Redirect

O - OSPF Intra, OI - OSPF Inter, OE1 - OSPF ext 1, OE2 - OSPF ext 2

ON1 - OSPF NSSA ext 1, ON2 - OSPF NSSA ext 2, a - Application

OI 2001:DB8:ACAD:1::/64 [110/4]

via FE80::41, GigabitEthernet0/0/1

OI 2001:DB8:ACAD:2::/64 [110/3]

via FE80::41, GigabitEthernet0/0/1

O 2001:DB8:ACAD:3::/64 [110/2]

via FE80::41, GigabitEthernet0/0/1

C 2001:DB8:ACAD:4::/64 [0/0]

via GigabitEthernet0/0/1, directly connected

L 2001:DB8:ACAD:4::2/128 [0/0]

via GigabitEthernet0/0/1, receive

OI 2001:DB8:ACAD:A::1/128 [110/4]

via FE80::41, GigabitEthernet0/0/1

OI 2001:DB8:ACAD:B::1/128 [110/3]

via FE80::41, GigabitEthernet0/0/1

OI 2001:DB8:ACAD:C::1/128 [110/2]

via FE80::41, GigabitEthernet0/0/1

O 2001:DB8:ACAD:D::1/128 [110/1]

via FE80::41, GigabitEthernet0/0/1

C 2001:DB8:ACAD:E::/64 [0/0]

via Loopback0, directly connected

L 2001:DB8:ACAD:E::1/128 [0/0]

via Loopback0, receive

L FF00::/8 [0/0]

via Null0, receive

**R6#show ipv6 ospf route**

OSPFv3 Router with ID (192.168.0.17) (Process ID 10)

Area 1

Intra-area Route List

\*> 2001:DB8:ACAD:3::/64, Intra, cost 2, area 1

via FE80::41, GigabitEthernet0/0/1

\* 2001:DB8:ACAD:4::/64, Intra, cost 1, area 1, Connected

via GigabitEthernet0/0/1

\*> 2001:DB8:ACAD:D::1/128, Intra, cost 1, area 1

via FE80::41, GigabitEthernet0/0/1

\* 2001:DB8:ACAD:E::1/128, Intra, cost 0, area 1, Connected

via Null0

Inter-area Route List

\*> 2001:DB8:ACAD:A::1/128, Inter, cost 4, area 1

via FE80::41, GigabitEthernet0/0/1

\*> 2001:DB8:ACAD:1::/64, Inter, cost 4, area 1

via FE80::41, GigabitEthernet0/0/1

\*> 2001:DB8:ACAD:2::/64, Inter, cost 3, area 1

via FE80::41, GigabitEthernet0/0/1

\*> 2001:DB8:ACAD:C::1/128, Inter, cost 2, area 1

via FE80::41, GigabitEthernet0/0/1

\*> 2001:DB8:ACAD:B::1/128, Inter, cost 3, area 1

via FE80::41, GigabitEthernet0/0/1

First Hop Forwarding Gateway Tree

:: on Null0, count 1

:: on GigabitEthernet0/0/1, count 1

FE80::41 on GigabitEthernet0/0/1, count 7

**R6#show ipv6 protocols**

IPv6 Routing Protocol is "connected"

IPv6 Routing Protocol is "application"

IPv6 Routing Protocol is "ND"

IPv6 Routing Protocol is "ospf 10"

Router ID 192.168.0.17

Number of areas: 1 normal, 0 stub, 0 nssa

Interfaces (Area 1):

Loopback0

GigabitEthernet0/0/1

Redistribution:

None

**Connectivity Tests**

**IPv4**

R2#ping 192.168.0.1

Sending 5, 100-byte ICMP Echos to 192.168.0.1, timeout is 2 seconds:

!!!!!

Success rate is 100 percent (5/5), round-trip min/avg/max = 1/1/1 ms

R2#ping 192.168.0.5

Type escape sequence to abort.

Sending 5, 100-byte ICMP Echos to 192.168.0.5, timeout is 2 seconds:

!!!!!

Success rate is 100 percent (5/5), round-trip min/avg/max = 1/1/1 ms

R2#ping 192.168.0.9

Type escape sequence to abort.

Sending 5, 100-byte ICMP Echos to 192.168.0.9, timeout is 2 seconds:

!!!!!

Success rate is 100 percent (5/5), round-trip min/avg/max = 1/1/1 ms

R2#ping 192.168.0.13

Type escape sequence to abort.

Sending 5, 100-byte ICMP Echos to 192.168.0.13, timeout is 2 seconds:

!!!!!

Success rate is 100 percent (5/5), round-trip min/avg/max = 1/1/1 ms

R2#ping 192.168.0.17

Type escape sequence to abort.

Sending 5, 100-byte ICMP Echos to 192.168.0.17, timeout is 2 seconds:

!!!!!

Success rate is 100 percent (5/5), round-trip min/avg/max = 1/1/1 ms

R2#ping 192.168.0.21

Type escape sequence to abort.

Sending 5, 100-byte ICMP Echos to 192.168.0.21, timeout is 2 seconds:

!!!!!

Success rate is 100 percent (5/5), round-trip min/avg/max = 1/1/1 ms

R2#ping 192.168.0.22

Type escape sequence to abort.

Sending 5, 100-byte ICMP Echos to 192.168.0.22, timeout is 2 seconds:

!!!!!

Success rate is 100 percent (5/5), round-trip min/avg/max = 1/1/1 ms

R2#ping 192.168.0.24

Type escape sequence to abort.

Sending 5, 100-byte ICMP Echos to 192.168.0.24, timeout is 2 seconds:

!!!!!

Success rate is 100 percent (5/5), round-trip min/avg/max = 1/1/1 ms

R2#ping 192.168.0.25

Type escape sequence to abort.

Sending 5, 100-byte ICMP Echos to 192.168.0.25, timeout is 2 seconds:

!!!!!

Success rate is 100 percent (5/5), round-trip min/avg/max = 1/1/1 ms

R2#ping 192.168.0.26

Type escape sequence to abort.

Sending 5, 100-byte ICMP Echos to 192.168.0.26, timeout is 2 seconds:

!!!!!

Success rate is 100 percent (5/5), round-trip min/avg/max = 1/1/1 ms

R2#ping 192.168.0.28

Type escape sequence to abort.

Sending 5, 100-byte ICMP Echos to 192.168.0.28, timeout is 2 seconds:

!!!!!

Success rate is 100 percent (5/5), round-trip min/avg/max = 1/1/2 ms

R2#ping 192.168.0.29

Type escape sequence to abort.

Sending 5, 100-byte ICMP Echos to 192.168.0.29, timeout is 2 seconds:

!!!!!

Success rate is 100 percent (5/5), round-trip min/avg/max = 1/1/1 ms

R2#ping 192.168.0.30

Type escape sequence to abort.

Sending 5, 100-byte ICMP Echos to 192.168.0.30, timeout is 2 seconds:

!!!!!

Success rate is 100 percent (5/5), round-trip min/avg/max = 1/1/1 ms

R2#ping 192.168.0.32

Type escape sequence to abort.

Sending 5, 100-byte ICMP Echos to 192.168.0.32, timeout is 2 seconds:

!!!!!

Success rate is 100 percent (5/5), round-trip min/avg/max = 1/1/1 ms

R2#ping 192.168.0.33

Type escape sequence to abort.

Sending 5, 100-byte ICMP Echos to 192.168.0.33, timeout is 2 seconds:

!!!!!

Success rate is 100 percent (5/5), round-trip min/avg/max = 1/1/1 ms

R2#ping 192.168.0.34

Type escape sequence to abort.

Sending 5, 100-byte ICMP Echos to 192.168.0.34, timeout is 2 seconds:

!!!!!

Success rate is 100 percent (5/5), round-trip min/avg/max = 1/1/1 ms

**IPv6**

R2#ping 2001:db8:acad:1::2

Type escape sequence to abort.

Sending 5, 100-byte ICMP Echos to 2001:DB8:ACAD:1::2, timeout is 2 seconds:

!!!!!

Success rate is 100 percent (5/5), round-trip min/avg/max = 1/2/8 ms

R2#ping 2001:db8:acad:2::1

Type escape sequence to abort.

Sending 5, 100-byte ICMP Echos to 2001:DB8:ACAD:2::1, timeout is 2 seconds:

!!!!!

Success rate is 100 percent (5/5), round-trip min/avg/max = 1/1/1 ms

R2#ping 2001:db8:acad:2::2

Type escape sequence to abort.

Sending 5, 100-byte ICMP Echos to 2001:DB8:ACAD:2::2, timeout is 2 seconds:

!!!!!

Success rate is 100 percent (5/5), round-trip min/avg/max = 1/1/1 ms

R2#ping 2001:db8:acad:3::1

Type escape sequence to abort.

Sending 5, 100-byte ICMP Echos to 2001:DB8:ACAD:3::1, timeout is 2 seconds:

!!!!!

Success rate is 100 percent (5/5), round-trip min/avg/max = 1/1/1 ms

R2#ping 2001:db8:acad:3::2

Type escape sequence to abort.

Sending 5, 100-byte ICMP Echos to 2001:DB8:ACAD:3::2, timeout is 2 seconds:

!!!!!

Success rate is 100 percent (5/5), round-trip min/avg/max = 1/1/1 ms

R2#ping 2001:db8:acad:4::1

Type escape sequence to abort.

Sending 5, 100-byte ICMP Echos to 2001:DB8:ACAD:4::1, timeout is 2 seconds:

!!!!!

Success rate is 100 percent (5/5), round-trip min/avg/max = 1/1/1 ms

R2#ping 2001:db8:acad:4::2

Type escape sequence to abort.

Sending 5, 100-byte ICMP Echos to 2001:DB8:ACAD:4::2, timeout is 2 seconds:

!!!!!

Success rate is 100 percent (5/5), round-trip min/avg/max = 1/1/1 ms

R2#ping 2001:db8:acad:a::1

Type escape sequence to abort.

Sending 5, 100-byte ICMP Echos to 2001:DB8:ACAD:A::1, timeout is 2 seconds:

!!!!!

Success rate is 100 percent (5/5), round-trip min/avg/max = 1/1/1 ms

R2#ping 2001:db8:acad:b::1

Type escape sequence to abort.

Sending 5, 100-byte ICMP Echos to 2001:DB8:ACAD:B::1, timeout is 2 seconds:

!!!!!

Success rate is 100 percent (5/5), round-trip min/avg/max = 1/1/1 ms

R2#ping 2001:db8:acad:c::1

Type escape sequence to abort.

Sending 5, 100-byte ICMP Echos to 2001:DB8:ACAD:C::1, timeout is 2 seconds:

!!!!!

Success rate is 100 percent (5/5), round-trip min/avg/max = 1/1/1 ms

R2#ping 2001:db8:acad:d::1

Type escape sequence to abort.

Sending 5, 100-byte ICMP Echos to 2001:DB8:ACAD:D::1, timeout is 2 seconds:

!!!!!

Success rate is 100 percent (5/5), round-trip min/avg/max = 1/1/2 ms

R2#ping 2001:db8:acad:e::1

Type escape sequence to abort.

Sending 5, 100-byte ICMP Echos to 2001:DB8:ACAD:E::1, timeout is 2 seconds:

!!!!!

Success rate is 100 percent (5/5), round-trip min/avg/max = 1/1/2 ms

**Problems**

The first problem encountered was a mistyped IPv4 address. While configuring OSPFv2, it was found that all routers could be pinged except for router 2. This was because the IPv4 address was mistyped as 192.158.0.21 instead of 192.168.0.21, making it unable to be pinged as it is on a different network than the connected router 3. This problem was found by running the **show ip interface brief** command, which showed that the IPv4 address of the G0/0/0 interface was misconfigured.

Afterwards, loopback addresses were checked, and the loopback addresses on some of the routers were unable to be reached. After running another **show ip interface brief** it was found that some of the router’s loopback addresses have not yet been configured.

While configuring OSPFv3, Router had a problem where using the command **ipv6 ospf <process-id> area <area number>** would produce an error that says that the router had not been configured for IPv6 routing. To enable IPv6 routing, the command **ipv6 unicast-routing** was entered in global configuration mode. However, going back into the interface and trying to enable OSPFv3 on the interface would produce the same error. So, the command **ipv6 unicast-routing** was entered in interface configuration mode before enabling the interface for OSPFv3.

Router 2 also had a problem where OSPFv3 went from FULL mode to DOWN mode because the interface was down or attached. This problem was solved by unplugging the cross-over cable and plugging them in again.

After verifying the connectivity, all the routers had successful pings to each other's IPv4 addresses, IPv6 global addresses, and IPv6 link-local addresses on their local networks, except for router 2. Router 2 worked for IPv4, but OSPFv3 was not enabled. Using the **show ipv6 protocols** command, OSPFv3 was not listed as an existing routing protocol. Despite activating the individual interfaces for OSPFv3, it was not recognized to be activated. It was hypothesized that it is due to the router being on version 16.9 instead of 15.5 like all routers, and the command structure had changed for version 16.9. A clue pointing towards this was that the **show ip ospf route** command did not work on 16.9, suggesting that the commands for OSPF may have been changed. In the end, the faulty version was 16.9.2, and booting from version 16.9.8 resolved the issue. As a result, the command structure was indeed not changed and there was a legitimate bug that has been patched by Cisco.

The next day, in order to circumvent the Router 2 problems, the running-configuration was saved and pasted into a new router. The OSPF configurations transferred across the routers but all the IPv6 addressing was not applied even though it was configured correctly in the saved configurations. The cause of this is unknown and was resolved by manually configuring the IPv6 addresses again.

Other problems that I had helped with were that OSPFv3 worked for all the routers except for loopback addresses. Every loopback address did not work. The solution was met using trial and error after guessing that the IPv6 addresses were not valid. After changing the IPv6 addresses, they worked with OSPFv3. Another problem I helped with was that two adjacent routers had not become OSPF neighbors and kept on having the message that there is an area mismatch on the connected network between them. Using **show ip interface brief** and **show ip protocols**, it was quickly seen that there was correct IPv4 addressing and activated interfaces for both routers. Using a ping test, it was found that there was no connectivity at all. Since the network layer was already verified, the physical connections were checked. The interfaces were incorrectly plugged in, making the interfaces with the wrong areas connected to each other. After creating connections with the correct interfaces, OSPF continued working as normal.

**Conclusion**

This lab demonstrates the usage of multi-area OSPF to both simplify and optimize the operations of routing. Because static routing requires a network administrator to manually configure every route on each router, the process gets convoluted and difficult to document quickly. Single area OSPF is much easier to configure and manage than static routing, but the routing information passed between the routers will create decent overhead for the routers every time a new router is added. As a result, multi-area OSPF finds a middle ground, with a little more complicated configurations, but lower routing overhead. The lab overall went smoothly, with not too many configuration problems or confusions in documentation. The configuration process was quick, and the connectivity tests mostly went well. The only real trouble was how fussy Router 2 was over the course of the lab.