Assignment Nine: Configure OSPF Networks

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Open Shortest Path First (OSPF) is a link-state routing protocol. Link state routing protocols differ from distance-vector based protocols such as RIP and EIGRP by having each router discover topology for itself rather than learn routes from other routers. Router's running link-state protocols each advertise information about their directly connected links and their neighbors. In addition, they advertise the state of these links to neighbors, hence where link-state got its name from.

OSPF was initially developed by an IETF task force to solve the issues of RIP. OSPF uses the vendor-neutral Dijkestra Shortest Path First algorithm to create a loop-free topology utilizing the lowest cost path to all known destinations. The OSPF process is relatively simple and is composed of seven major steps.

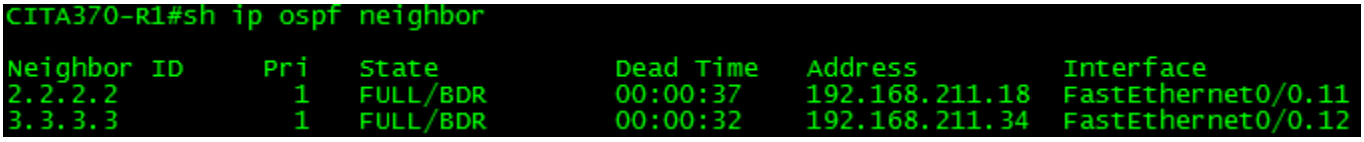
First, OSPF routers send hello packets on all interfaces with OSPF enabled. When another OSPF router receives the hello packet, a neighbor relationship is formed. This relationship is furthered by the creation of adjacencies. Adjacencies are formed after each router determines the area and router type of its neighbor. After adjacencies are formed, Link-State Advertisements of LSA's are sent out via all adjacencies. LSA's contain information about all of a router's links, its neighbors, and the state of these links. After receiving an LSA, a router records it in its link-state database and then proceeds to forward it to all other neighbors. During this process of forwarding LSA's to other neighbors, all routers build identical link-state databases. After the databases propagate, the routers each use the Dijkestra SPF algorithm to create a loop-free topology utilizing the lowest cost path to all known destinations. Finally, the router builds its routing table based upon the results of the SPF topology calculations.

There are four types of routers in an OSPF domain; internal, backbone, area border and AS boundary. An internal router is a router with all interfaces residing within the same area. A backbone router is a router with at least one interface in the backbone (Area 0). An area border router (ABR) is a router with interfaces in two or more areas serving to connect them. An autonomous system boundary router (ASBR) is a router with interfaces in both an OSPF domain and other routing domains external to the OSPF domain. It serves as the border of the routing domain and is a gateway to networks in other domains.

There are eleven LSA types but only seven of them are seen in common use in OSPFv2. OSPF Type-9,10, and 11 are opaque LSAs as defined in RFC 2370.

Ref-lstype	Name	v2 Equivalent	Purpose
0x2001	Router LSA	Type-1	Advertises Router and neighbors
0x2002	Network LSA	Type-2	Represents interfaces connected to subnet
0x2003	Network Summary LSA	Type-3	Summarizes type1&2 to another area
0x2004	ASBR Summary LSA	Type-4	Advertises host route to reach an ASBR
0x2005	AS External LSA	Type-5	Represents injected external routes
0x2006	Group Membership LSA	Type-6	For MOSPF (Multicast OSPF extension)
0x2007	NSSA External LSA	Type-7	NSSA External Routes (Only in NSSA)
0x2008	External Attributes LSA	Type-8	iBGP Replacement (Cisco Unsupported)
	Opaque LSA (link-local scope)	Type-9	OSPFv3 - prefixes for stub and transit networks
	Opaque LSA (area-local scope)	Type-10	Usually used for traffic engineering (MPLS)
	Opaque LSA (AS scope)	Type-11	Opaque equivalent of the type 5

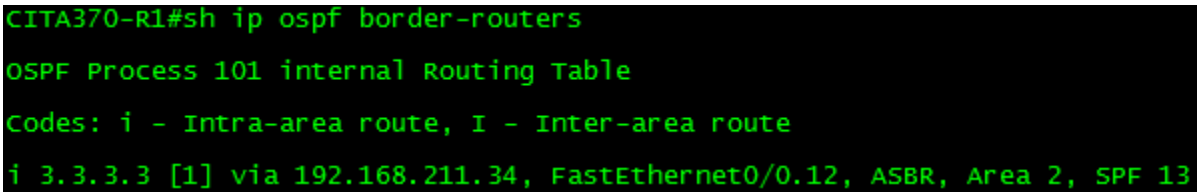
OSPF LSAs are flooded between areas differently depending on the LSA number and the area type. Type-1 and 2 LSAs are always present in an area and never leave their area. Type-3 and 5 LSAs are redistributed mutually between connected standard OSPF areas. Type-4 LSAs are injected into the backbone (Area 0) in a one-way fashion. In stub areas, only Type-3 LSAs are exchanged. In addition, a default route is injected one-way into the stub area. A totally stubby receives only an injected default route; it does not receive Type-3, 4 or 5 LSAs. A Not So Stubby Area (NSSA) is a more complicated and Cisco proprietary situation. NSSA's utilize Type-7 LSA to represent external routes. These Type-7 LSAs are then injected into Area 0 as Type-5 LSAs and flooded throughout all compatible areas. Type-4 LSAs may also be injected from a NSSA into the backbone. Basically, standard areas can contain Type-1, 2, 3, 4, and 5. The backbone is also considered a standard area. Stub areas can contain Type-1, 2, and 3 LSAs and a default route is substituted for external routes. Totally stubby areas can only contain Type-1 and 2 LSAs, and a single Type-3 LSA which defines a default route. Not-so-stubby areas contain the same LSAs as stub areas but Type-7 LSAs are converted to type-5 by ABRs to be flooded to the rest of the OSPF domain.



```
CITA370-R1#sh ip ospf neighbor

Neighbor ID     Pri   State           Dead Time   Address         Interface
2.2.2.2           1   FULL/BDR        00:00:37    192.168.211.18  FastEthernet0/0.11
3.3.3.3           1   FULL/BDR        00:00:32    192.168.211.34  FastEthernet0/0.12
```

Figure 1

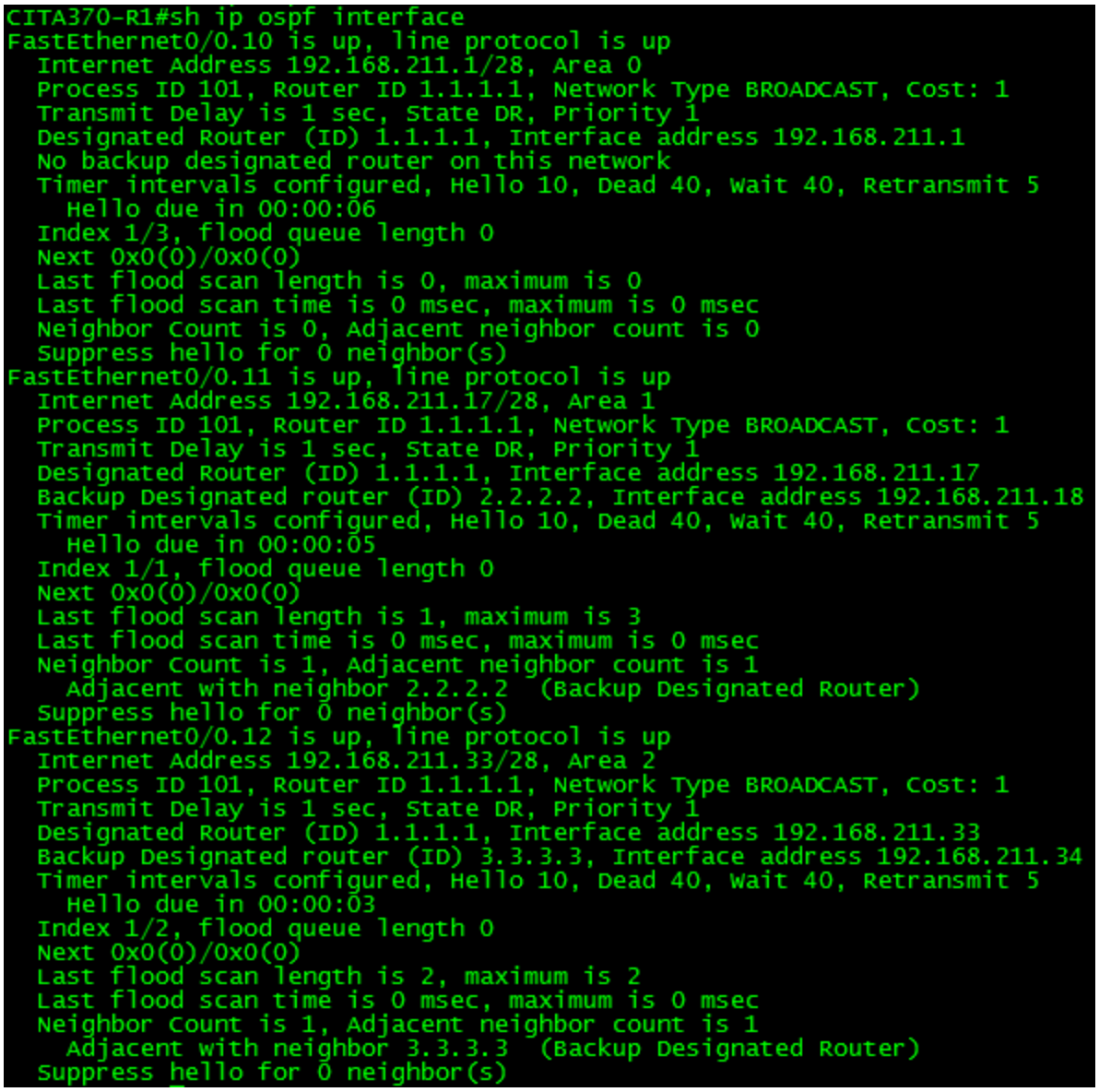
Figure 1 shows the OSPF neighbor relationships formed on CITA370-R1. CITA370-R1 is the backbone router.



```
CITA370-R1#sh ip ospf border-routers

OSPF Process 101 internal Routing Table

Codes: i - Intra-area route, I - Inter-area route

i 3.3.3.3 [1] via 192.168.211.34, FastEthernet0/0.12, ASBR, Area 2, SPF 13
```

Figure 2

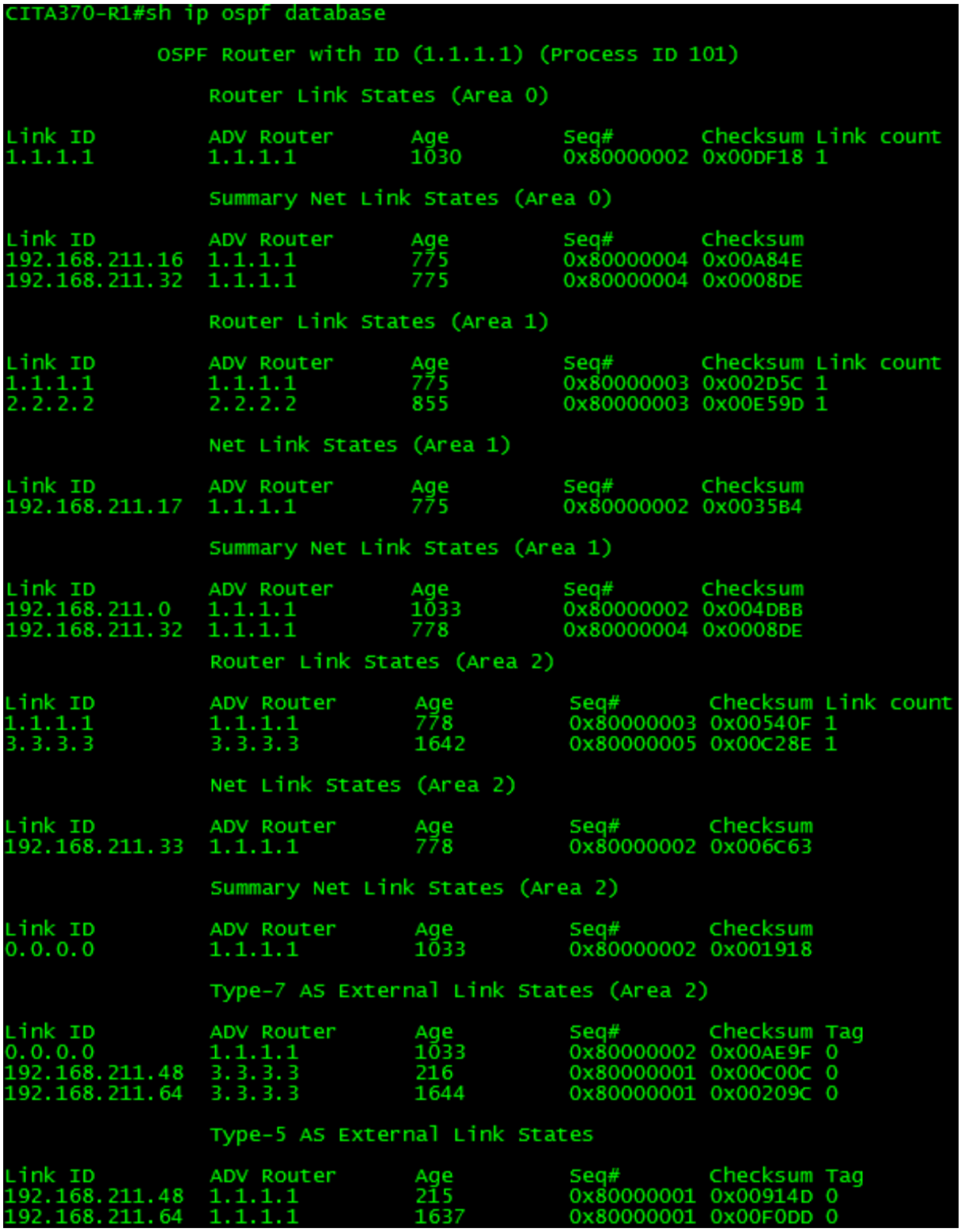
Figure 2 shows routers which are border routers, and in this case 3.3.3.3 aka CITA370-R3 is an ASBR. It is listed as an ASBR because it connects to other routing domains by performing redistribution.



```
CITA370-R1#sh ip ospf interface
FastEthernet0/0.10 is up, line protocol is up
  Internet Address 192.168.211.1/28, Area 0
  Process ID 101, Router ID 1.1.1.1, Network Type BROADCAST, Cost: 1
  Transmit Delay is 1 sec, State DR, Priority 1
  Designated Router (ID) 1.1.1.1, Interface address 192.168.211.1
  No backup designated router on this network
  Timer intervals configured, Hello 10, Dead 40, Wait 40, Retransmit 5
    Hello due in 00:00:06
  Index 1/3, flood queue length 0
  Next 0x0(0)/0x0(0)
  Last flood scan length is 0, maximum is 0
  Last flood scan time is 0 msec, maximum is 0 msec
  Neighbor Count is 0, Adjacent neighbor count is 0
  Suppress hello for 0 neighbor(s)
FastEthernet0/0.11 is up, line protocol is up
  Internet Address 192.168.211.17/28, Area 1
  Process ID 101, Router ID 1.1.1.1, Network Type BROADCAST, Cost: 1
  Transmit Delay is 1 sec, State DR, Priority 1
  Designated Router (ID) 1.1.1.1, Interface address 192.168.211.17
  Backup Designated router (ID) 2.2.2.2, Interface address 192.168.211.18
  Timer intervals configured, Hello 10, Dead 40, Wait 40, Retransmit 5
    Hello due in 00:00:05
  Index 1/1, flood queue length 0
  Next 0x0(0)/0x0(0)
  Last flood scan length is 1, maximum is 3
  Last flood scan time is 0 msec, maximum is 0 msec
  Neighbor Count is 1, Adjacent neighbor count is 1
    Adjacent with neighbor 2.2.2.2  (Backup Designated Router)
  Suppress hello for 0 neighbor(s)
FastEthernet0/0.12 is up, line protocol is up
  Internet Address 192.168.211.33/28, Area 2
  Process ID 101, Router ID 1.1.1.1, Network Type BROADCAST, Cost: 1
  Transmit Delay is 1 sec, State DR, Priority 1
  Designated Router (ID) 1.1.1.1, Interface address 192.168.211.33
  Backup Designated router (ID) 3.3.3.3, Interface address 192.168.211.34
  Timer intervals configured, Hello 10, Dead 40, Wait 40, Retransmit 5
    Hello due in 00:00:03
  Index 1/2, flood queue length 0
  Next 0x0(0)/0x0(0)
  Last flood scan length is 2, maximum is 2
  Last flood scan time is 0 msec, maximum is 0 msec
  Neighbor Count is 1, Adjacent neighbor count is 1
    Adjacent with neighbor 3.3.3.3  (Backup Designated Router)
  Suppress hello for 0 neighbor(s)
```

Figure 3

Figure 3 lists the state of the interfaces on CITA370-R1 which is a backbone router and is also an ABR because it links area Zero, One, and Two.



```
CITA370-R1#sh ip ospf database

            OSPF Router with ID (1.1.1.1) (Process ID 101)

                Router Link States (Area 0)

Link ID         ADV Router      Age         Seq#       Checksum Link count
1.1.1.1         1.1.1.1         1030        0x80000002 0x00DF18 1

                Summary Net Link States (Area 0)

Link ID         ADV Router      Age         Seq#       Checksum
192.168.211.16  1.1.1.1         775         0x80000004 0x00A84E
192.168.211.32  1.1.1.1         775         0x80000004 0x0008DE

                Router Link States (Area 1)

Link ID         ADV Router      Age         Seq#       Checksum Link count
1.1.1.1         1.1.1.1         775         0x80000003 0x002D5C 1
2.2.2.2         2.2.2.2         855         0x80000003 0x00E59D 1

                Net Link States (Area 1)

Link ID         ADV Router      Age         Seq#       Checksum
192.168.211.17  1.1.1.1         775         0x80000002 0x0035B4

                Summary Net Link States (Area 1)

Link ID         ADV Router      Age         Seq#       Checksum
192.168.211.0   1.1.1.1         1033        0x80000002 0x004DBB
192.168.211.32  1.1.1.1         778         0x80000004 0x0008DE
                Router Link States (Area 2)

Link ID         ADV Router      Age         Seq#       Checksum Link count
1.1.1.1         1.1.1.1         778         0x80000003 0x00540F 1
3.3.3.3         3.3.3.3         1642        0x80000005 0x00C28E 1

                Net Link States (Area 2)

Link ID         ADV Router      Age         Seq#       Checksum
192.168.211.33  1.1.1.1         778         0x80000002 0x006C63

                Summary Net Link States (Area 2)

Link ID         ADV Router      Age         Seq#       Checksum
0.0.0.0         1.1.1.1         1033        0x80000002 0x001918

                Type-7 AS External Link States (Area 2)

Link ID         ADV Router      Age         Seq#       Checksum Tag
0.0.0.0         1.1.1.1         1033        0x80000002 0x00AE9F 0
192.168.211.48  3.3.3.3         216         0x80000001 0x00C00C 0
192.168.211.64  3.3.3.3         1644        0x80000001 0x00209C 0

                Type-5 AS External Link States

Link ID         ADV Router      Age         Seq#       Checksum Tag
192.168.211.48  1.1.1.1         215         0x80000001 0x00914D 0
192.168.211.64  1.1.1.1         1637        0x80000001 0x00F0DD 0
```

Figure 4

Figure 4 shows the OSPF database of backbone router CITA370-R1.

```
CITA370-R2#sh ip ospf database

            OSPF Router with ID (2.2.2.2) (Process ID 101)

                Router Link States (Area 1)

Link ID         ADV Router      Age         Seq#       Checksum Link count
1.1.1.1         1.1.1.1         1086        0x80000003 0x002D5C 1
2.2.2.2         2.2.2.2         1163        0x80000003 0x00E59D 1

                Net Link States (Area 1)

Link ID         ADV Router      Age         Seq#       Checksum
192.168.211.17  1.1.1.1         1086        0x80000002 0x0035B4

                Summary Net Link States (Area 1)

Link ID         ADV Router      Age         Seq#       Checksum
192.168.211.0   1.1.1.1         1341        0x80000002 0x004DBB
192.168.211.32  1.1.1.1         1086        0x80000004 0x0008DE

                Type-5 AS External Link States

Link ID         ADV Router      Age         Seq#       Checksum Tag
192.168.211.48  1.1.1.1         517         0x80000001 0x00914D 0
192.168.211.64  1.1.1.1         73          0x80000002 0x00EEDE 0
```

Figure 5

Figure 5 shows the OSPF database of CITA370-R2 which is a member of Area 1. Area 1 is an OSPF Normal area.

```
CITA370-R3#sh ip ospf database

            OSPF Router with ID (3.3.3.3) (Process ID 101)

                Router Link States (Area 2)

Link ID         ADV Router      Age         Seq#       Checksum Link count
1.1.1.1         1.1.1.1         1176        0x80000003 0x00540F 1
3.3.3.3         3.3.3.3         126         0x80000006 0x00C08F 1

                Net Link States (Area 2)

Link ID         ADV Router      Age         Seq#       Checksum
192.168.211.33  1.1.1.1         1176        0x80000002 0x006C63

                Summary Net Link States (Area 2)

Link ID         ADV Router      Age         Seq#       Checksum
0.0.0.0         1.1.1.1         1431        0x80000002 0x001918

                Type-7 AS External Link States (Area 2)

Link ID         ADV Router      Age         Seq#       Checksum Tag
0.0.0.0         1.1.1.1         1431        0x80000002 0x00AE9F 0
192.168.211.48  3.3.3.3         606         0x80000001 0x00C00C 0
192.168.211.64  3.3.3.3         127         0x80000002 0x001E9D 0
```

Figure 6

Figure 6 shows the OSPF database of CITA370-R3. R3 is a member of Not-So-Stubby Area 2. You can see here that Type-7 LSA's are present, indicative of a NSSA.

```
CITA370-R1#sh ip route
Codes: C - connected, S - static, I - IGRP, 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, E - EGP
       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

Gateway of last resort is not set

     192.168.211.0/28 is subnetted, 5 subnets
O N2    192.168.211.48
           [110/20] via 192.168.211.34, 00:13:29, FastEthernet0/0.12
C       192.168.211.32 is directly connected, FastEthernet0/0.12
C       192.168.211.16 is directly connected, FastEthernet0/0.11
C       192.168.211.0 is directly connected, FastEthernet0/0.10
O N2    192.168.211.64
           [110/20] via 192.168.211.34, 00:37:13, FastEthernet0/0.12
```

Figure 7

Figure 7 shows the route table of CITA370-R1.

```
CITA370-R2#sh ip route
Codes: C - connected, S - static, I - IGRP, 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, E - EGP
       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

Gateway of last resort is not set

     192.168.211.0/28 is subnetted, 5 subnets
O E2    192.168.211.48
           [110/20] via 192.168.211.17, 00:12:34, FastEthernet0/0.11
O IA    192.168.211.32
           [110/2] via 192.168.211.17, 00:53:08, FastEthernet0/0.11
C       192.168.211.16 is directly connected, FastEthernet0/0.11
O IA    192.168.211.0 [110/2] via 192.168.211.17, 00:55:56, FastEthernet0/0.11
O E2    192.168.211.64
           [110/20] via 192.168.211.17, 00:36:17, FastEthernet0/0.11
```

Figure 8

Figure 8 shows the route table of CITA370-R2.

```
CITA370-R3#sh ip route
Codes: C - connected, S - static, I - IGRP, 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, E - EGP
       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

Gateway of last resort is 192.168.211.33 to network 0.0.0.0

     192.168.211.0/28 is subnetted, 3 subnets
C       192.168.211.48 is directly connected, FastEthernet0/0.13
C       192.168.211.32 is directly connected, FastEthernet0/0.12
C       192.168.211.64 is directly connected, FastEthernet0/0.14
O*IA 0.0.0.0/0 [110/2] via 192.168.211.33, 00:35:24, FastEthernet0/0.12
```

Figure 9

Figure 9 shows the route table of CITA370-R3.

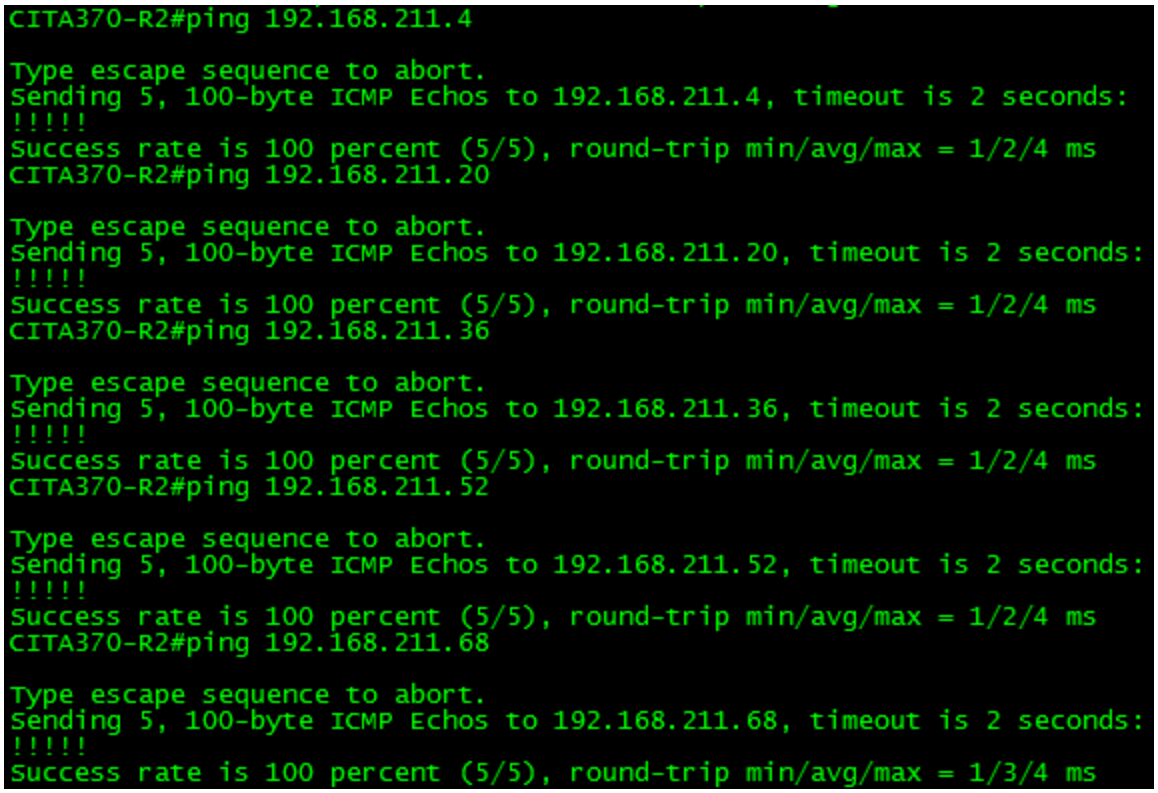


Figure 10

Figure 10 demonstrates a verification of connectivity from Area 1 – OSPF Normal.

OSPF NSSA - Area 2 Connectivity Verification

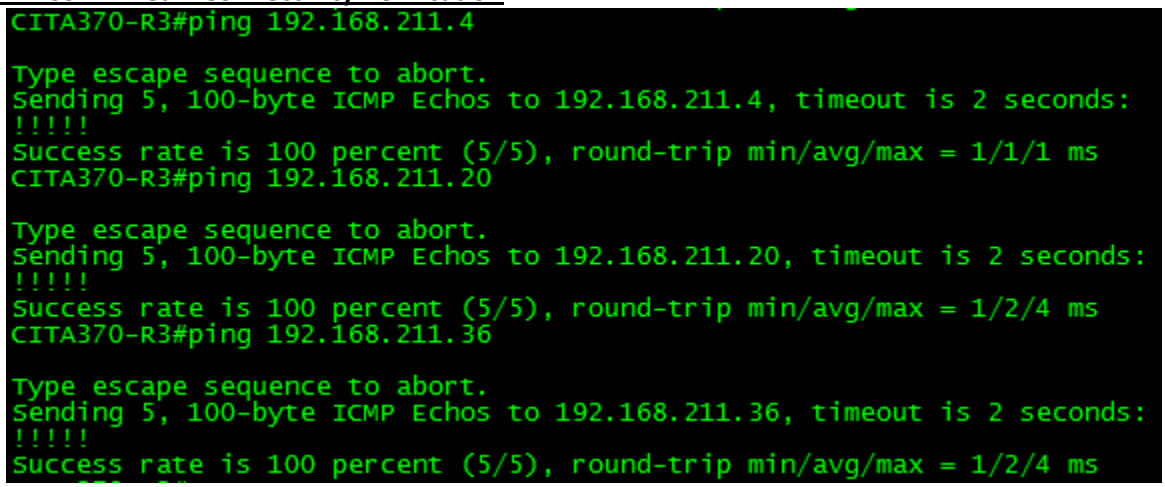


Figure 11

Figure 11 demonstrates a verification of connectivity from Area 2 – OSPF NSSA.

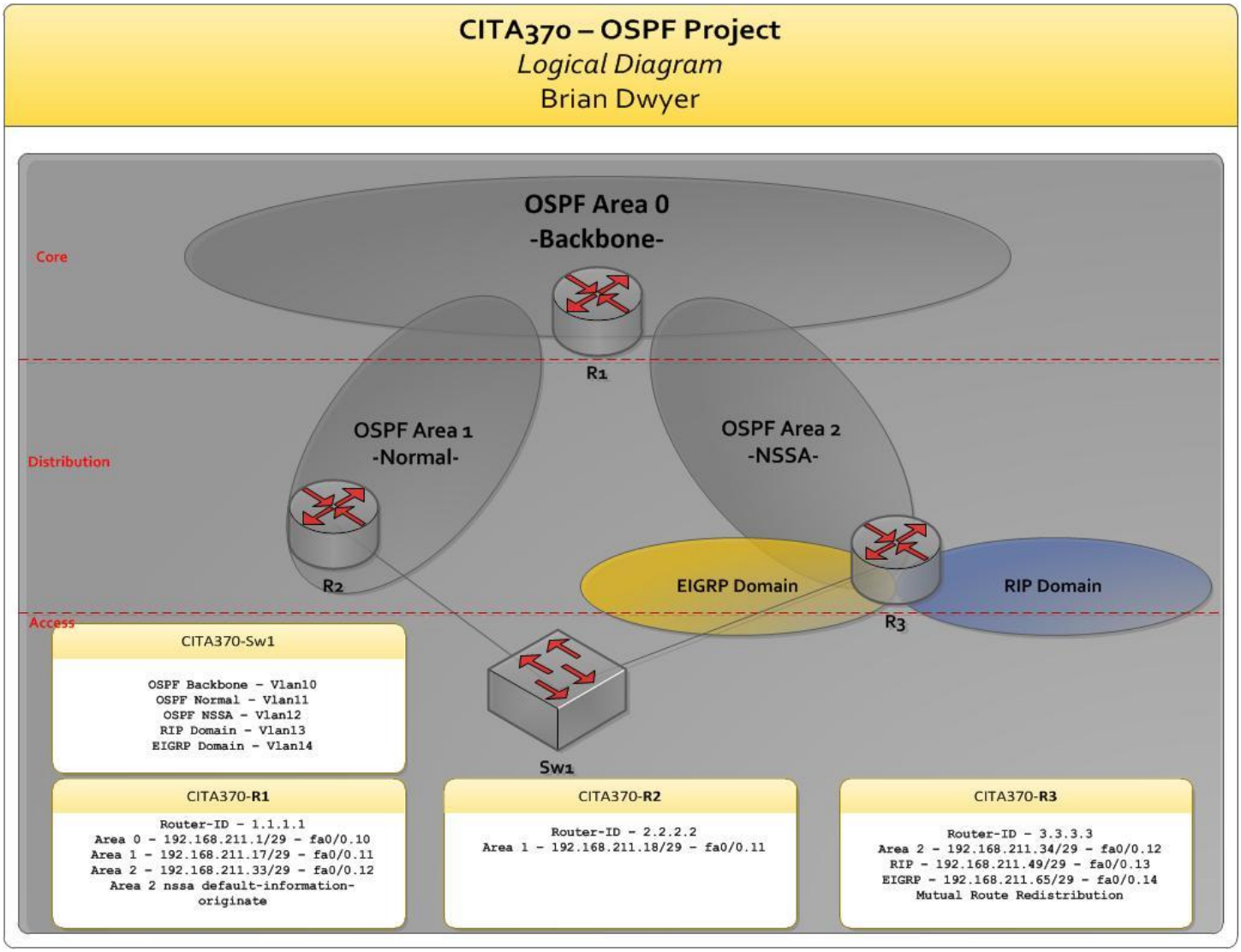


Figure 12 – Logical Diagram

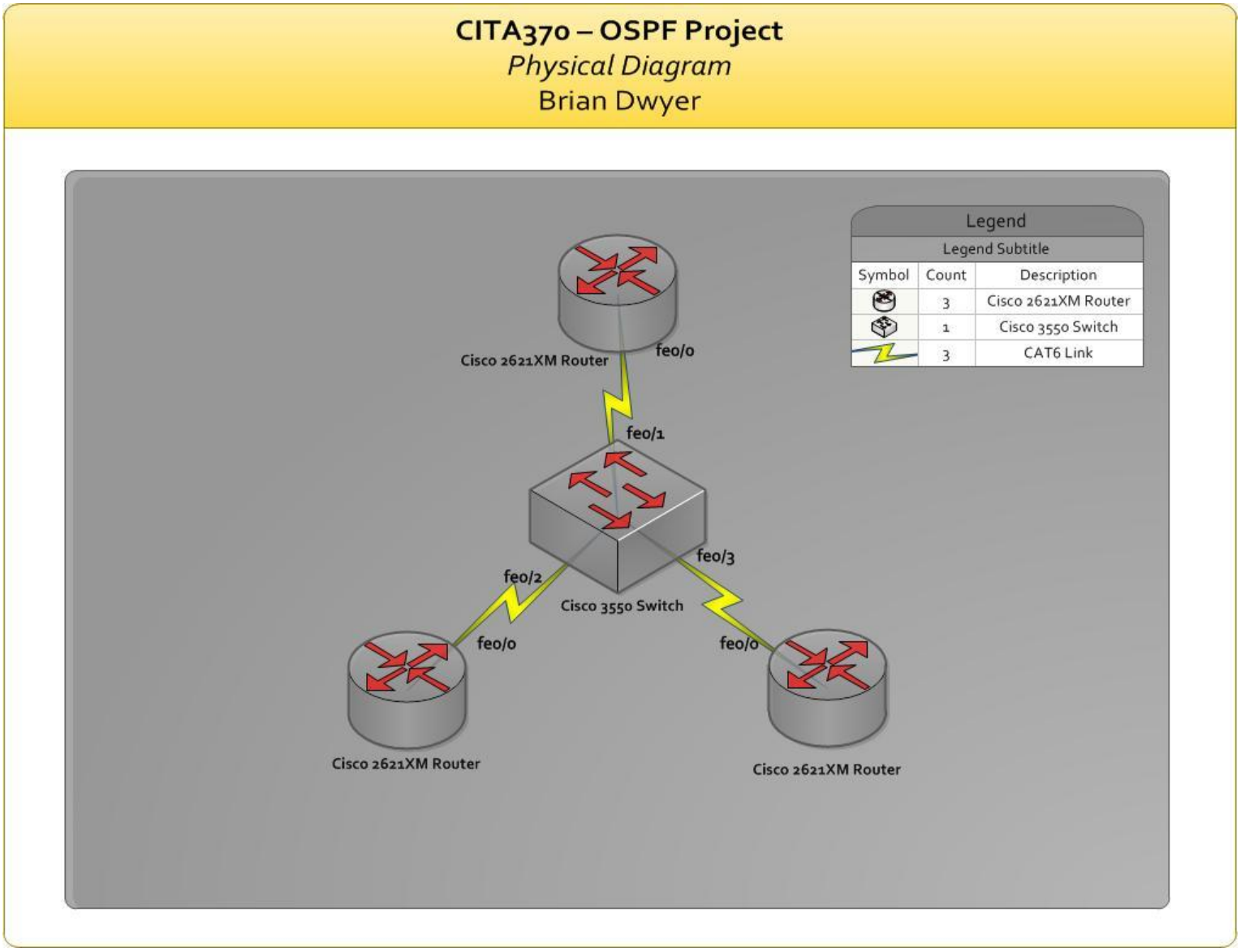


Figure 13 – Physical Diagram

CONFIGURATION FILES

- **Router 1 Configuration**

```
CITA370-R1#sh run
Building configuration...
Current configuration : 1104 bytes
!
version 12.2
service timestamps debug uptime
service timestamps log uptime
no service password-encryption
!
hostname CITA370-R1
!
memory-size iomem 15
ip subnet-zero
!
call rsvp-sync
!
!
interface FastEthernet0/0
 no ip address
 duplex auto
 speed auto
!
interface FastEthernet0/0.10
 description OSPF_Backbone
 encapsulation dot1Q 10
 ip address 192.168.211.1 255.255.255.240
!
interface FastEthernet0/0.11
 description OSPF_Normal
 encapsulation dot1Q 11
 ip address 192.168.211.17 255.255.255.240
!
interface FastEthernet0/0.12
 description OSPF_NSSA
 encapsulation dot1Q 12
 ip address 192.168.211.33 255.255.255.240
!
interface Serial0/0
 no ip address
 shutdown
!
interface FastEthernet0/1
 no ip address
 shutdown
 duplex auto
 speed auto
!
router ospf 101
 router-id 1.1.1.1
 log-adjacency-changes
 area 2 nssa default-information-originate no-summary
 network 192.168.211.0 0.0.0.15 area 0
 network 192.168.211.16 0.0.0.15 area 1
 network 192.168.211.32 0.0.0.15 area 2
!
ip classless
ip http server
!
dial-peer cor custom
!
line con 0
line aux 0
line vty 0 4
!
end
```

- **Router 2 Configuration**

```
hostname CITA370-R2

interface FastEthernet0/0
 no ip address
 duplex auto
 speed auto
!
interface FastEthernet0/0.11
 description OSPF_Normal
 encapsulation dot1Q 11
 ip address 192.168.211.18 255.255.255.240
router ospf 101
 router-id 2.2.2.2
 log-adjacency-changes
 network 192.168.211.16 0.0.0.15 area 1
```

- **Router 3 Configuration (Solution One – Route Map to Overcome RIP Limitation)**

```
hostname CITA370-R3
interface FastEthernet0/0.12
 description OSPF_NSSA
 encapsulation dot1Q 12
 ip address 192.168.211.34 255.255.255.240
!
interface FastEthernet0/0.13
 description RIP_Domain
 encapsulation dot1Q 13
 ip address 192.168.211.49 255.255.255.240
!
interface FastEthernet0/0.14
 description EIGRP_Domain
 encapsulation dot1Q 14
 ip address 192.168.211.65 255.255.255.240
router eigrp 1
 redistribute ospf 101
 network 192.168.211.64 0.0.0.15
 no auto-summary
!
router ospf 101
 router-id 3.3.3.3
 log-adjacency-changes
 area 2 nssa
 redistribute eigrp 1 subnets
 redistribute rip subnets
 network 192.168.211.32 0.0.0.15 area 2
!
router rip
 version 2
 redistribute static route-map RIP_CIDR_FIX
 redistribute ospf 101
 no auto-summary
!
ip classless
ip route 192.168.211.48 255.255.255.240 FastEthernet0/0.13
no ip http server
!
ip prefix-list RIP_CIDR_FIX seq 5 permit 192.168.211.48/28
```

- **Router 3 Configuration (Possibility Two – Passive Interfaces to overcome RIP Limitation)**

```
hostname CITA370-R3
!
interface FastEthernet0/0.12
 description OSPF_NSSA
 encapsulation dot1Q 12
 ip address 192.168.211.34 255.255.255.240
!
interface FastEthernet0/0.13
 description RIP_Domain
 encapsulation dot1Q 13
 ip address 192.168.211.49 255.255.255.240
!
interface FastEthernet0/0.14
 description EIGRP_Domain
 encapsulation dot1Q 14
 ip address 192.168.211.65 255.255.255.240
router eigrp 1
 redistribute ospf 101
 passive-interface FastEthernet0/0.12
 passive-interface FastEthernet0/0.13
 network 192.168.211.64 0.0.0.15
 no auto-summary
!
router ospf 101
 router-id 3.3.3.3
 log-adjacency-changes
 area 2 nssa
 redistribute eigrp 1 subnets
 redistribute rip subnets
 passive-interface FastEthernet0/0.13
 passive-interface FastEthernet0/0.14
 network 192.168.211.32 0.0.0.15 area 2
!
router rip
 version 2
 redistribute ospf 101
 passive-interface FastEthernet0/0.12
 passive-interface FastEthernet0/0.14
 network 192.168.211.0
 no auto-summary
```

- **Switch 1 Configuration**

```
hostname CITA370-Sw1
!
interface FastEthernet0/1
 switchport trunk encapsulation dot1q
 switchport mode trunk
!
interface FastEthernet0/2
 switchport trunk encapsulation dot1q
 switchport mode trunk
!
interface FastEthernet0/3
 switchport trunk encapsulation dot1q
 switchport mode trunk
!
interface FastEthernet0/4
!
interface FastEthernet0/10
 switchport access vlan 10
!
interface FastEthernet0/11
 switchport access vlan 11
!
interface FastEthernet0/12
 switchport access vlan 12
!
interface FastEthernet0/13
 switchport access vlan 13
!
interface FastEthernet0/14
 switchport access vlan 14
!
!
interface Vlan10
 description OSPF_Backbone
 ip address 192.168.211.4 255.255.255.240
!
interface Vlan11
 description OSPF_Normal
 ip address 192.168.211.20 255.255.255.240
!
interface Vlan12
 description OSPF_NSSA
 ip address 192.168.211.36 255.255.255.240
!
interface Vlan13
 description RIP_Domain
 ip address 192.168.211.52 255.255.255.240
!
interface Vlan14
 description EIGRP_Domain
 ip address 192.168.211.68 255.255.255.240
```

Works Cited

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