

浙江大学实验报告

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课程名称: 计算机网络 指导老师: 张泉方 电子邮件: wutongcs@zju.edu.cn
实验名称: 动态路由协议 OSPF 配置 实验类型: 操作型 同组同学: 无

一、实验目的

- 理解链路状态路由协议的工作原理
- 理解 OSPF 协议的工作机制
- 掌握配置和调试 OSPF 协议的方法

二、实验内容

- 使用网线连接 PC 和路由器，并配置 PC 和路由器各端口的 IP 地址，让 PC 彼此能够与路由器接口互相 ping 通。
- 用网线连接多个路由器，并配置互联端口的 IP 地址，使直接连接的 2 个路由器能相互 ping 通。
- 在 Area 0 的路由器上启用 OSPF 动态路由协议，让各路由器能够互相学习到新的路由信息，进而使区域内的 PC 能够相互 ping 通。
- 在 Area 1 的路由器上启用 OSPF 动态路由协议，让区域内和区域间各路由器能够互相学习到新的路由信息。
- 在 Area 2 的路由器上启用 OSPF 动态路由协议，在 NBMA（非广播多路访问）网络拓扑上配置 OSPF 协议，让区域内和区域间各路由器能够互相学习到新的路由信息。
- 在 Area 3（不与 Area 0 直接连接）的路由器上启用 OSPF 动态路由协议，在边界路由器上建立虚链路，让 Area 3 的路由器能够学习到新的路由信息，进而使 Area 3 的路由器能够学习到其他区域的路由信息。
- 在上述各种情况下，观察各路由器上的路由表和 OSPF 运行数据，并验证各 PC 能够相互 ping 通。
- 断开某些链路，观察 OSPF 事件和路由表变化。
- 在 Area 边界路由器上配置路由聚合。

三、主要仪器设备

- PC 机（模拟器）
- 交换机（模拟器）
- 路由器（模拟器）

四、操作方法与实验步骤

- 按照拓扑图连接 PC 和路由器。
- 设计好 PC 和路由器各端口的 IP 地址、子网掩码。
- 配置各 PC 的默认网关，分别设置为所连路由器的相应端口 IP 地址。
- 配置各路由器互联端口的 IP 地址，使直连的 2 个路由器能相互 ping 通。
- 先后给路由器 R1、R2、R3 配置 RIP 协议和 OSPF 协议，比较两者选择的路由差别。
- 给 Area 1、Area 2 的路由器配置 OSPF 协议，观察区域间路由信息交换。
- 给 Area 3 的路由器配置 OSPF 协议。由于 Area 3 没有物理上直接与 Area 0 连接，所以需要利用 Area 1 作为中介，在 R4 和 R9 之间为 Area 3 建立一个虚链路。
- 观察各路由器的路由表，查看路由器做出的选择是否符合预期。
- 通过 ping 检查各 PC 之间的连通性。
- 实时显示路由器之间交换的路由信息事件，理解 OSPF 协议交互过程。
- 断开某些网络连接，查看 OSPF 的数据变化以及路由表的变化，并测试 PC 间的连通性。

五、实验数据记录和处理

1. 设计好每个 PC、路由器各接口的 IP 地址及掩码，并标注在拓扑图上。

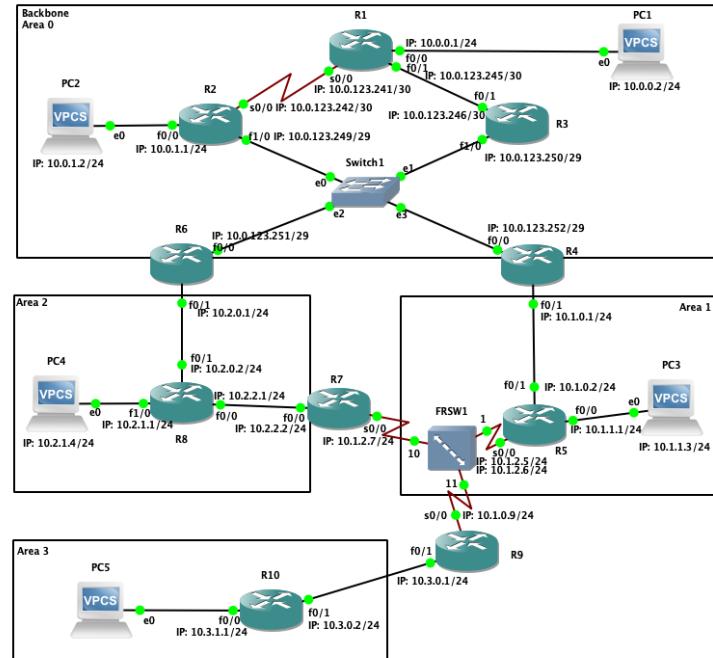


图 1: 实验拓扑图

2. 给路由器 R1、R2、R3 各接口配置 IP 地址并激活。配置 PC1、PC2 的 IP 地址和默认网关，测试 PC1 与 R1、PC2 与 R2 的连通性。

R1 配置命令：

```
1 R1#config terminal
2 R1(config)#interface f0/0
3 R1(config-if)#ip address 10.0.0.1 255.255.255.0
4 R1(config-if)#no shutdown
5 R1(config-if)#interface f0/1
6 R1(config-if)#ip address 10.0.123.245 255.255.255.252
7 R1(config-if)#no shutdown
8 R1(config-if)#interface s0/0
9 R1(config-if)#ip address 10.0.123.241 255.255.255.252
10 R1(config-if)#encapsulation hdlc
11 R1(config-if)#clock rate 128000
12 R1(config-if)#no shutdown
13 R1(config-if)#exit
```

R2 配置命令：

```
1 R2#config terminal
2 R2(config)#interface f0/0
3 R2(config-if)#ip address 10.0.1.1 255.255.255.0
4 R2(config-if)#no shutdown
5 R2(config-if)#interface f1/0
6 R2(config-if)#ip address 10.0.123.249 255.255.255.248
7 R2(config-if)#no shutdown
8 R2(config-if)#interface s0/0
9 R2(config-if)#ip address 10.0.123.242 255.255.255.252
10 R2(config-if)#encapsulation hdlc
11 R2(config-if)#no shutdown
12 R2(config-if)#exit
```

R3 配置命令：

```
1 R3#config terminal
2 R3(config)#interface f0/1
3 R3(config-if)#ip address 10.0.123.246 255.255.255.252
4 R3(config-if)#no shutdown
5 R3(config-if)#interface f1/0
6 R3(config-if)#ip address 10.0.123.250 255.255.255.248
7 R3(config-if)#no shutdown
8 R3(config-if)#exit
```

PC1 配置命令：

```
1 PC1> ip 10.0.0.2 255.255.0.0 10.0.0.1
```

PC2 配置命令：

```
1 PC2> ip 10.0.1.2 255.255.0.0 10.0.1.1
```

测试 PC1 与 R1、PC2 与 R2 的连通性：

```
[PC1]> ping 10.0.0.1
84 bytes from 10.0.0.1 icmp_seq=1 ttl=255 time=29.988 ms
84 bytes from 10.0.0.1 icmp_seq=2 ttl=255 time=7.612 ms
84 bytes from 10.0.0.1 icmp_seq=3 ttl=255 time=7.238 ms
84 bytes from 10.0.0.1 icmp_seq=4 ttl=255 time=4.048 ms
84 bytes from 10.0.0.1 icmp_seq=5 ttl=255 time=7.403 ms
```

图 2: PC1 能 ping 通 R1

```
[PC2]> ping 10.0.1.1
84 bytes from 10.0.1.1 icmp_seq=1 ttl=255 time=20.944 ms
84 bytes from 10.0.1.1 icmp_seq=2 ttl=255 time=2.915 ms
84 bytes from 10.0.1.1 icmp_seq=3 ttl=255 time=7.000 ms
84 bytes from 10.0.1.1 icmp_seq=4 ttl=255 time=16.026 ms
84 bytes from 10.0.1.1 icmp_seq=5 ttl=255 time=2.433 ms
```

图 3: PC2 能 ping 通 R2

3. 在 R1、R2、R3 上启用 RIP 动态路由协议，并宣告各接口所在子网地址。

R1 配置命令：

```
1 R1(config)#router rip
2 R1(config-router)#network 10.0.0.0
3 R1(config-router)#version 2
```

R2 配置命令：

```
1 R2(config)#router rip
2 R2(config-router)#version 2
3 R2(config-router)#network 10.0.0.0
```

R3 配置命令：

```
1 R3(config)#router rip
2 R3(config-router)#version 2
3 R3(config-router)#network 10.0.0.0
```

4. 查看 R1、R2、R3 的路由表，跟踪 PC1 到 PC2 的路由。

R1 到 PC2 的子网下一跳的路由器是 10.0.123.242。

R2 到 PC1 的子网下一跳的路由器是 10.0.123.241。

PC1 到 PC2，经过的路由顺序是 R1、R2。

```
[R1]#show ip route
Codes: 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

Gateway of last resort is not set

  10.0.0.0/8 is variably subnetted, 5 subnets, 3 masks
C     10.0.0.0/24 is directly connected, FastEthernet0/0
R     10.0.1.0/24 [120/1] via 10.0.123.242, 00:00:03, Serial0/0
C     10.0.123.240/30 is directly connected, Serial0/0
C     10.0.123.244/30 is directly connected, FastEthernet0/1
R     10.0.123.248/29 [120/1] via 10.0.123.246, 00:00:20, FastEthernet0/1
                                [120/1] via 10.0.123.242, 00:00:03, Serial0/0
```

图 4: R1 路由表

```
[R2]#show ip route
Codes: 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

Gateway of last resort is not set

  10.0.0.0/8 is variably subnetted, 5 subnets, 3 masks
R     10.0.0.0/24 [120/1] via 10.0.123.241, 00:00:17, Serial0/0
C     10.0.1.0/24 is directly connected, FastEthernet0/0
C     10.0.123.240/30 is directly connected, Serial0/0
R     10.0.123.244/30 [120/1] via 10.0.123.250, 00:00:16, FastEthernet1/0
                                [120/1] via 10.0.123.241, 00:00:17, Serial0/0
C     10.0.123.248/29 is directly connected, FastEthernet1/0
```

图 5: R2 路由表

```
[R3]#show ip route
Codes: 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

Gateway of last resort is not set

  10.0.0.0/8 is variably subnetted, 5 subnets, 3 masks
R     10.0.0.0/24 [120/1] via 10.0.123.245, 00:00:25, FastEthernet0/1
R     10.0.1.0/24 [120/1] via 10.0.123.249, 00:00:04, FastEthernet1/0
R     10.0.123.240/30 [120/1] via 10.0.123.249, 00:00:04, FastEthernet1/0
                                [120/1] via 10.0.123.245, 00:00:25, FastEthernet0/1
C     10.0.123.244/30 is directly connected, FastEthernet0/1
C     10.0.123.248/29 is directly connected, FastEthernet1/0
```

图 6: R3 路由表

```
[PC1]> trace 10.0.1.2
trace to 10.0.1.2, 8 hops max, press Ctrl+C to stop
1 10.0.0.1 8.534 ms 9.985 ms 10.116 ms
2 10.0.123.242 8.656 ms 10.050 ms 9.163 ms
3 *10.0.1.2 18.836 ms (ICMP type:3, code:3, Destination port unreachable)
```

图 7: PC1 到 PC2 的路由跟踪

5. 启用路由器 R1 的 OSPF 动态路由协议，并配置各接口所属区域为 Area 0。

R1 配置命令：

```
1 R1#config terminal
2 R1(config)#router ospf 48
3 R1(config-router)#network 10.0.0.0 0.0.255.255 area 0
```

6. 先给 R2 的回环接口配置 IP 地址，然后再启用路由器 R2 的 OSPF 动态路由协议，设置包括回环接口在内的各接口所属区域。

R2 配置命令：

```
1 R2#config terminal
2 R2(config)#interface loopback 0
3 R2(config-if)#ip address 10.0.20.1 255.255.255.252
4 R2(config-if)#router ospf 48
5 R2(config-router)#network 10.0.0.0 0.0.255.255 area 0
```

7. 启用路由器 R3 的 OSPF 动态路由协议，手工指定 Router ID，并设置各接口所属区域为 Area 0。

R3 配置命令：

```
1 R3#config terminal
2 R3(config)#router ospf 48
3 R3(config-router)#router-id 10.0.30.1
4 R3(config-router)#network 10.0.0.0 0.0.255.255 area 0
```

8. 查看 OSPF 数据库，并标出各路由器的 Router ID。

R1 的 Router ID 为 10.0.123.245（取自接口 f0/1 的 IP）。与 R1 连接的有 3 个路由器，其 ID 分别是 10.0.20.1、10.0.30.1、10.0.123.245，有 2 条链路，其 ID 分别是 10.0.123.245、10.0.123.249。

R2 的 Router ID 为 10.0.20.1（取自接口 loopback 0 的 IP）。与 R2 连接的有 3 个路由器，其 ID 分别是 10.0.20.1、10.0.30.1、10.0.123.245，有 2 条链路，其 ID 分别是 10.0.123.245、10.0.123.249。

R3 的 Router ID 为 10.0.30.1。与 R3 连接的有 3 个路由器，其 ID 分别是 10.0.20.1、10.0.30.1、10.0.123.245，有 2 条链路，其 ID 分别是 10.0.123.245、10.0.123.249。

```
R1#show ip ospf database
OSPF Router with ID (10.0.123.245) (Process ID 48)
Router Link States (Area 0)

Link ID      ADV Router      Age      Seq#      Checksum Link count
10.0.20.1    10.0.20.1    161      0x80000002 0x00E5B3 5
10.0.30.1    10.0.30.1    161      0x80000001 0x003F90 2
10.0.123.245 10.0.123.245 160      0x80000003 0x001756 4

Net Link States (Area 0)

Link ID      ADV Router      Age      Seq#      Checksum
10.0.123.245 10.0.123.245 160      0x80000001 0x00DFC1
10.0.123.249 10.0.20.1    161      0x80000001 0x00FC5D
```

图 8: R1 的 OSPF 数据库

```
R2#show ip ospf database
OSPF Router with ID (10.0.20.1) (Process ID 48)
Router Link States (Area 0)

Link ID      ADV Router      Age      Seq#      Checksum Link count
10.0.20.1    10.0.20.1    165      0x80000002 0x00E5B3 5
10.0.30.1    10.0.30.1    166      0x80000001 0x003F90 2
10.0.123.245 10.0.123.245 166      0x80000003 0x001756 4

Net Link States (Area 0)

Link ID      ADV Router      Age      Seq#      Checksum
10.0.123.245 10.0.123.245 166      0x80000001 0x00DFC1
10.0.123.249 10.0.20.1    165      0x80000001 0x00FC5D
```

图 9: R2 的 OSPF 数据库

```
R3#show ip ospf database
OSPF Router with ID (10.0.30.1) (Process ID 48)
Router Link States (Area 0)

Link ID      ADV Router      Age      Seq#      Checksum Link count
10.0.20.1    10.0.20.1    167      0x80000002 0x00E5B3 5
10.0.30.1    10.0.30.1    166      0x80000001 0x003F90 2
10.0.123.245 10.0.123.245 168      0x80000003 0x001756 4

Net Link States (Area 0)

Link ID      ADV Router      Age      Seq#      Checksum
10.0.123.245 10.0.123.245 168      0x80000001 0x00DFC1
10.0.123.249 10.0.20.1    167      0x80000001 0x00FC5D
```

图 10: R3 的 OSPF 数据库

9. 在路由器 R1 上显示 OSPF 接口数据，标记各接口的 cost 值，网络类型，邻接关系及其 Router ID，广播类型的网络，再标出 DR 或者 BDR 角色。

R1 的 f0/0 连接的网络类型为 BROADCAST，Cost=10，DR 的 Router ID 是 10.0.123.245，接口 IP 是 10.0.0.1。

R1 的 f0/1 连接的网络类型为 BROADCAST, Cost=10, 邻居 Router ID=10.0.30.1, DR 的 Router ID 是 10.0.123.245, 接口 IP 是 10.0.123.245, BDR 的 Router ID 是 10.0.30.1, 接口 IP 是 10.0.123.246。

R1 的 s0/0 连接的网络类型为 POINT_TO_POINT, Cost=64, 邻居 Router ID=10.0.20.1。

```
FastEthernet0/0 is up, line protocol is up
  Internet Address 10.0.0.1/24, Area 0
  Process ID 48, Router ID 10.0.123.245, Network Type BROADCAST, Cost: 10
  Transmit Delay is 1 sec, State DR, Priority 1
  Designated Router (ID) 10.0.123.245, Interface address 10.0.0.1
  No backup designated router on this network
  Timer intervals configured, Hello 10, Dead 40, Wait 40, Retransmit 5
    oob-resync timeout 40
    Hello due in 00:00:02
  Supports Link-local Signaling (LLS)
  Index 1/1, 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)
```

图 11: R1 的 f0/0

```
R1#show ip ospf interface
FastEthernet0/1 is up, line protocol is up
  Internet Address 10.0.123.245/30, Area 0
  Process ID 48, Router ID 10.0.123.245, Network Type BROADCAST, Cost: 10
  Transmit Delay is 1 sec, State DR, Priority 1
  Designated Router (ID) 10.0.123.245, Interface address 10.0.123.245
  Backup Designated router (ID) 10.0.30.1, Interface address 10.0.123.246
  Timer intervals configured, Hello 10, Dead 40, Wait 40, Retransmit 5
    oob-resync timeout 40
    Hello due in 00:00:06
  Supports Link-local Signaling (LLS)
  Index 3/3, flood queue length 0
  Next 0x0(0)/0x0(0)
  Last flood scan length is 1, 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 10.0.30.1 (Backup Designated Router)
  Suppress hello for 0 neighbor(s)
```

图 12: R1 的 f0/1

```
Serial0/0 is up, line protocol is up
  Internet Address 10.0.123.241/30, Area 0
  Process ID 48, Router ID 10.0.123.245, Network Type POINT_TO_POINT, Cost: 64
  Transmit Delay is 1 sec, State POINT_TO_POINT
  Timer intervals configured, Hello 10, Dead 40, Wait 40, Retransmit 5
    oob-resync timeout 40
    Hello due in 00:00:04
  Supports Link-local Signaling (LLS)
  Index 2/2, flood queue length 0
  Next 0x0(0)/0x0(0)
  Last flood scan length is 1, maximum is 1
  Last flood scan time is 0 msec, maximum is 0 msec
  Neighbor Count is 1, Adjacent neighbor count is 1
    Adjacent with neighbor 10.0.20.1
  Suppress hello for 0 neighbor(s)
```

图 13: R1 的 s0/0

10. 10. 查看 R1、R2、R3 的路由表，跟踪 PC1 到 PC2 的路由。

R1 到 PC2 的子网 OSPF 选择的下一跳 IP 地址是 10.0.123.246，RIP 不考虑线路带宽，只考虑经过的路由器个数，OSPF 考虑线路 cost，带宽越大，cost 越小。OSPF 的优先级高。

R2 到 PC1 的子网下一跳的路由器是 10.0.123.250。

PC1 到 PC2，经过的路由顺序是 R1、R3、R2。

```
R1#show ip route
Codes: 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

Gateway of last resort is not set

      10.0.0.0/8 is variably subnetted, 7 subnets, 4 masks
C       10.0.0.0/24 is directly connected, FastEthernet0/0
O       10.0.1.0/24 [110/21] via 10.0.123.246, 00:29:22, FastEthernet0/1
R       10.0.20.0/30 [120/1] via 10.0.123.242, 00:00:19, Serial0/0
O       10.0.20.1/32 [110/12] via 10.0.123.246, 00:29:22, FastEthernet0/1
C       10.0.123.240/30 is directly connected, Serial0/0
C       10.0.123.244/30 is directly connected, FastEthernet0/1
O       10.0.123.248/29 [110/11] via 10.0.123.246, 00:29:24, FastEthernet0/1
```

图 14: R1 路由表

```
R2#show ip route
Codes: 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

Gateway of last resort is not set

      10.0.0.0/8 is variably subnetted, 6 subnets, 3 masks
O       10.0.0.0/24 [110/21] via 10.0.123.250, 00:29:29, FastEthernet1/0
C       10.0.1.0/24 is directly connected, FastEthernet0/0
C       10.0.20.0/30 is directly connected, Loopback0
C       10.0.123.240/30 is directly connected, Serial0/0
O       10.0.123.244/30 [110/11] via 10.0.123.250, 00:29:29, FastEthernet1/0
C       10.0.123.248/29 is directly connected, FastEthernet1/0
```

图 15: R2 路由表

```
R3#show ip route
Codes: 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

Gateway of last resort is not set

  10.0.0.0/8 is variably subnetted, 7 subnets, 4 masks
O     10.0.0.0/24 [110/20] via 10.0.123.245, 00:29:28, FastEthernet0/1
O     10.0.1.0/24 [110/11] via 10.0.123.249, 00:29:28, FastEthernet1/0
R     10.0.20.0/30 [120/1] via 10.0.123.249, 00:00:14, FastEthernet1/0
O     10.0.20.1/32 [110/2] via 10.0.123.249, 00:29:28, FastEthernet1/0
O     10.0.123.240/30 [110/65] via 10.0.123.249, 00:29:28, FastEthernet1/0
C     10.0.123.244/30 is directly connected, FastEthernet0/1
C     10.0.123.248/29 is directly connected, FastEthernet1/0
```

图 16: R3 路由表

```
PC1> trace 10.0.1.2
trace to 10.0.1.2, 8 hops max, press Ctrl+C to stop
1 10.0.0.1 9.661 ms 9.229 ms 9.329 ms
2 10.0.123.246 29.959 ms 30.821 ms 29.520 ms
3 10.0.123.249 51.245 ms 49.997 ms 50.577 ms
4 *10.0.1.2 59.819 ms (ICMP type:3, code:3, Destination port unreachable)
```

图 17: PC1 到 PC2 的路由跟踪

11. 断开 R1 和 R3 的接口，再次显示 R1 的路由表，标记到达 PC2 所在子网的下一跳。

R1 配置命令：

```
1 R1#config terminal
2 R1(config)#interface f0/1
3 R1(config-if)#shutdown
```

R3 配置命令：

```
1 R3#config terminal
2 R3(config)#interface f0/1
3 R3(config-if)#shutdown
```

R1 到 PC2 的子网下一跳 IP 地址是 10.0.123.242。

```
R1#show ip route
Codes: 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

Gateway of last resort is not set

  10.0.0.0/8 is variably subnetted, 7 subnets, 4 masks
C    10.0.0.0/24 is directly connected, FastEthernet0/0
O    10.0.1.0/24 [110/74] via 10.0.123.242, 00:00:26, Serial0/0
R    10.0.20.0/30 [120/1] via 10.0.123.242, 00:00:08, Serial0/0
O    10.0.20.1/32 [110/65] via 10.0.123.242, 00:00:26, Serial0/0
C    10.0.123.240/30 is directly connected, Serial0/0
C    10.0.123.244/30 is directly connected, FastEthernet0/1
O    10.0.123.248/29 [110/65] via 10.0.123.242, 00:00:26, Serial0/0
```

图 18: R1 路由表

12. 保存 R1 配置后重启路由器，查看 R1 的 Router ID。

R1 的 Router ID 变为 10.0.123.241，取自 s0/0 接口的 IP 地址。

```
R1#show ip ospf database
OSPF Router with ID (10.0.123.241) (Process ID 48)

Router Link States (Area 0)
Link ID      ADV Router      Age      Seq#      Checksum Link count
10.0.20.1    10.0.20.1      38       0x80000004 0x005942 5
10.0.30.1    10.0.30.1      170      0x80000006 0x00E069 2
10.0.123.241 10.0.123.241  28       0x80000002 0x004442 3
10.0.123.245 10.0.123.245  203      0x80000008 0x00F780 3

Net Link States (Area 0)
Link ID      ADV Router      Age      Seq#      Checksum
10.0.123.249 10.0.20.1      1668     0x80000002 0x00FA5E
```

图 19: R1 的 OSPF 数据库

13. 在 R1 上打开 OSPF 事件调试，然后重新连接 R1 和 R3 的接口，待到与 R3 的邻居关系为 Full 后关闭 debug，最后查看邻居关系。

R1 和 R3 重新建立邻接关系时经历了 5 个状态：INIT、2WAY、EXSTART、EXCHANG、FULL。

```
*Mar 1 00:08:17.403: OSPF: Rcv DBD from 10.0.30.1 on FastEthernet0/1 seq 0x17FC opt 0x52 flag 0x7 len 32 mtu 1500 state INIT
*Mar 1 00:08:17.403: OSPF: 2 Way Communication to 10.0.30.1 on FastEthernet0/1, state 2WAY
*Mar 1 00:08:17.403: OSPF: Neighbor change Event on interface FastEthernet0/1
*Mar 1 00:08:17.403: OSPF: DR/BDR election on FastEthernet0/1
*Mar 1 00:08:17.403: OSPF: Elect BDR 10.0.30.1
*Mar 1 00:08:17.403: OSPF: Elect DR 10.0.123.245
*Mar 1 00:08:17.403: OSPF: DR: 10.0.123.245 (Id) BDR: 10.0.30.1 (Id)
*Mar 1 00:08:17.403: OSPF: Send DBD to 10.0.30.1 on FastEthernet0/1 seq 0xF75 opt 0x52 flag 0x7 len 32
*Mar 1 00:08:17.403: OSPF: First DBD and we are not SLAVE
*Mar 1 00:08:17.407: OSPF: Rcv hello from 10.0.30.1 area 0 from FastEthernet0/1 10.0.123.246
*Mar 1 00:08:17.411: OSPF: Neighbor change Event on interface FastEthernet0/1
*Mar 1 00:08:17.411: OSPF: DR/BDR election on FastEthernet0/1
*Mar 1 00:08:17.411: OSPF: Elect BDR 10.0.30.1
*Mar 1 00:08:17.411: OSPF: Elect DR 10.0.123.245
*Mar 1 00:08:17.411: OSPF: DR: 10.0.123.245 (Id) BDR: 10.0.30.1 (Id)
*Mar 1 00:08:17.411: OSPF: Neighbor change Event on interface FastEthernet0/1
*Mar 1 00:08:17.411: OSPF: DR/BDR election on FastEthernet0/1
*Mar 1 00:08:17.411: OSPF: Elect BDR 10.0.30.1
*Mar 1 00:08:17.411: OSPF: Elect DR 10.0.123.245
*Mar 1 00:08:17.411: OSPF: DR: 10.0.123.245 (Id) BDR: 10.0.30.1 (Id)
*Mar 1 00:08:17.415: OSPF: End of hello processing
*Mar 1 00:08:17.423: OSPF: Rcv DBD from 10.0.30.1 on FastEthernet0/1 seq 0xF75 opt 0x52 flag 0x2 len 132 mtu 1500 state EXSTART
*Mar 1 00:08:17.423: OSPF: NBR Negotiation Done. We are the MASTER
*Mar 1 00:08:17.423: OSPF: Send DBD to 10.0.30.1 on FastEthernet0/1 seq 0xF76 opt 0x52 flag 0x3 len 132
*Mar 1 00:08:17.443: OSPF: Rcv DBD from 10.0.30.1 on FastEthernet0/1 seq 0xF76 opt 0x52 flag 0x0 len 32 mtu 1500 state EXCHANGE
*Mar 1 00:08:17.443: OSPF: Send DBD to 10.0.30.1 on FastEthernet0/1 seq 0xF77 opt 0x52 flag 0x1 len 32
*Mar 1 00:08:17.447: OSPF: Rcv DBD from 10.0.30.1 on FastEthernet0/1 seq 0xF77 opt 0x52 flag 0x0 len 32 mtu 1500 state EXCHANGE
*Mar 1 00:08:17.447: OSPF: Exchange Done with 10.0.30.1 on FastEthernet0/1
*Mar 1 00:08:17.451: OSPF: Synchronized with 10.0.30.1 on FastEthernet0/1, state FULL
*Mar 1 00:08:17.451: %OSPF-5-ADJCHG: Process 48, Nbr 10.0.30.1 on FastEthernet0/1 from LOADING to FULL, Loading Done
```

图 20: R1 和 R3 重新建立邻接关系的事件记录

R1 的 OSPF 邻居详细信息：

```
[R1]#show ip ospf neighbor detail
Neighbor 10.0.30.1, interface address 10.0.123.246
  In the area 0 via interface FastEthernet0/1
  Neighbor priority is 1, State is FULL, 12 state changes
  DR is 10.0.123.245 BDR is 10.0.123.246
    Options is 0x12 in Hello (E-bit L-bit )
    Options is 0x52 in DBD (E-bit L-bit 0-bit)
    LLS Options is 0x1 (LR)
    Dead timer due in 00:00:32
    Neighbor is up for 00:04:57
    Index 2/2, retransmission queue length 0, number of retransmission 2
    First 0x0(0)/0x0(0) Next 0x0(0)/0x0(0)
    Last retransmission scan length is 1, maximum is 1
    Last retransmission scan time is 0 msec, maximum is 0 msec
Neighbor 10.0.20.1, interface address 10.0.123.242
  In the area 0 via interface Serial0/0
  Neighbor priority is 0, State is FULL, 6 state changes
  DR is 0.0.0.0 BDR is 0.0.0.0
    Options is 0x12 in Hello (E-bit L-bit )
    Options is 0x52 in DBD (E-bit L-bit 0-bit)
    LLS Options is 0x1 (LR)
    Dead timer due in 00:00:32
    Neighbor is up for 00:13:03
    Index 1/1, retransmission queue length 0, number of retransmission 1
    First 0x0(0)/0x0(0) Next 0x0(0)/0x0(0)
    Last retransmission scan length is 1, maximum is 1
    Last retransmission scan time is 0 msec, maximum is 0 msec
```

图 21: R1 的 OSPF 邻居详细信息

14. 给 R4、R6 的回环接口、f0/0 接口配置 IP 地址并激活，启用 OSPF 协议，接口均属于 Area 0。过一会儿查看 R4 和 R6 的邻居信息。

R4 配置命令：

```

1 R4#config terminal
2 R4(config)#interface loopback 0
3 R4(config-if)#ip address 10.0.40.1 255.255.255.252
4 R4(config-if)#interface f0/0
5 R4(config-if)#ip address 10.0.123.252 255.255.255.248
6 R4(config-if)#no shutdown
7 R4(config-if)#router ospf 48
8 R4(config-router)#router-id 10.0.40.1
9 R4(config-router)#network 10.0.0.0 0.0.255.255 area 0

```

R6 配置命令：

```

1 R6#config terminal
2 R6(config)#interface loopback 0
3 R6(config-if)#ip address 10.0.60.1 255.255.255.252
4 R6(config-if)#interface f0/0
5 R6(config-if)#ip address 10.0.123.251 255.255.255.248
6 R6(config-if)#no shutdown
7 R6(config-if)#router ospf 48
8 R6(config-router)#router-id 10.0.60.1
9 R6(config-router)#network 10.0.0.0 0.0.255.255 area 0

```

R4#show ip ospf neighbor					
Neighbor ID	Pri	State	Dead Time	Address	Interface
10.0.20.1	1	FULL/BDR	00:00:37	10.0.123.249	FastEthernet0/0
10.0.30.1	1	FULL/DR	00:00:35	10.0.123.250	FastEthernet0/0
10.0.60.1	1	2WAY/DROTHER	00:00:33	10.0.123.251	FastEthernet0/0

图 22: R4 的邻居关系

R6#show ip ospf neighbor					
Neighbor ID	Pri	State	Dead Time	Address	Interface
10.0.20.1	1	FULL/BDR	00:00:38	10.0.123.249	FastEthernet0/0
10.0.30.1	1	FULL/DR	00:00:39	10.0.123.250	FastEthernet0/0
10.0.40.1	1	2WAY/DROTHER	00:00:31	10.0.123.252	FastEthernet0/0

图 23: R6 的邻居关系

15. 给 R4 的 f0/1 接口、R5 的回环接口、f0/1 和 f0/0 接口配置 IP 地址、激活端口，并启用 OSPF 协议，各接口均属于 Area 1。配置 PC3 的 IP 地址和默认路由。过一会儿，查看 R2、R5 上的路由表，标出区域间路由 (IA)，测试 PC3 与 PC1 的连通性。

R4 配置命令：

```

1 R4(config)#interface f0/1

```

```

2 R4(config-if)#ip address 10.1.0.1 255.255.255.0
3 R4(config-if)#no shutdown
4 R4(config-if)#router ospf 48
5 R4(config-router)#network 10.1.0.0 0.0.255.255 area 1

```

R5 配置命令：

```

1 R5(config)#interface f0/1
2 R5(config-if)#ip address 10.1.0.2 255.255.255.0
3 R5(config-if)#no shutdown
4 R5(config)#interface f0/0
5 R5(config-if)#ip address 10.1.1.1 255.255.255.0
6 R5(config-if)#no shutdown
7 R5(config)#interface loopback 0
8 R5(config-if)#ip address 10.1.50.1 255.255.255.252
9 R5(config)#router ospf 48
10 R5(config-router)#network 10.1.0.0 0.0.255.255 area 1

```

PC3 配置命令：

```

1 PC3> ip 10.1.1.3 255.255.255.0 10.1.1.1

```

R2 的路由表中，目标为 Area 1 中的子网的下一跳 IP 地址均为 10.0.123.252，从 R2 的 f1/0 接口发出。
R5 的路由表中，目标为 Area 0 中的子网的下一跳 IP 地址均为 10.1.0.1，从 R5 的 f0/1 接口发出。

```

[R2]#show ip route
Codes: 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

Gateway of last resort is not set

  10.0.0.0/8 is variably subnetted, 11 subnets, 4 masks
O IA  10.1.1.0/24 [110/21] via 10.0.123.252, 00:00:01, FastEthernet1/0
O     10.0.0.0/24 [110/21] via 10.0.123.250, 00:18:59, FastEthernet1/0
O IA  10.1.0.0/24 [110/11] via 10.0.123.252, 00:18:59, FastEthernet1/0
C     10.0.1.0/24 is directly connected, FastEthernet0/0
C     10.0.20.0/30 is directly connected, Loopback0
O     10.0.40.1/32 [110/2] via 10.0.123.252, 00:18:59, FastEthernet1/0
O     10.0.60.1/32 [110/2] via 10.0.123.251, 00:19:01, FastEthernet1/0
O IA  10.1.50.1/32 [110/12] via 10.0.123.252, 00:00:02, FastEthernet1/0
C     10.0.123.240/30 is directly connected, Serial0/0
O     10.0.123.244/30 [110/11] via 10.0.123.250, 00:19:01, FastEthernet1/0
C     10.0.123.248/29 is directly connected, FastEthernet1/0

```

图 24: R2 路由表

```
R5#show ip route
Codes: 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

Gateway of last resort is not set

  10.0.0.0/8 is variably subnetted, 11 subnets, 4 masks
C       10.1.1.0/24 is directly connected, FastEthernet0/0
O IA    10.0.0.0/24 [110/40] via 10.1.0.1, 00:00:00, FastEthernet0/1
C       10.1.0.0/24 is directly connected, FastEthernet0/1
O IA    10.0.1.0/24 [110/30] via 10.1.0.1, 00:00:00, FastEthernet0/1
O IA    10.0.20.1/32 [110/21] via 10.1.0.1, 00:00:00, FastEthernet0/1
O IA    10.0.40.1/32 [110/11] via 10.1.0.1, 00:00:00, FastEthernet0/1
O IA    10.0.60.1/32 [110/21] via 10.1.0.1, 00:00:01, FastEthernet0/1
C       10.1.50.0/30 is directly connected, Loopback0
O IA    10.0.123.240/30 [110/84] via 10.1.0.1, 00:00:01, FastEthernet0/1
O IA    10.0.123.244/30 [110/30] via 10.1.0.1, 00:00:01, FastEthernet0/1
O IA    10.0.123.248/29 [110/20] via 10.1.0.1, 00:00:01, FastEthernet0/1
```

图 25: R5 路由表

```
[PC3]> ping 10.0.0.2
10.0.0.2 icmp_seq=1 timeout
84 bytes from 10.0.0.2 icmp_seq=2 ttl=60 time=66.960 ms
84 bytes from 10.0.0.2 icmp_seq=3 ttl=60 time=75.157 ms
84 bytes from 10.0.0.2 icmp_seq=4 ttl=60 time=71.096 ms
84 bytes from 10.0.0.2 icmp_seq=5 ttl=60 time=75.644 ms
```

图 26: PC3 能 ping 通 PC1

16. 分别在 R2、R4、R5 上显示 OSPF 数据库信息，关注是否出现其他 Area 的信息。

R2 没有 Area 1 的具体信息，但是该区域的子网地址 10.1.0.0、10.1.1.0、10.1.50.1 由路由器 R4 汇聚后以区域间链路的形式进行通告。

R4 有 Area 1 和 Area 0 的具体信息，由于 R4 是区域边界路由器（ABR），所以对区域内的链路进行了汇聚，然后以区域间路由的形式向其他区域进行链路状态通告（LSA），其中：向 Area 0 通告的属于 Area 1 的链路有 10.1.0.0、10.1.1.0、10.1.50.1；向 Area 1 通告的属于 Area 0 的链路有 10.0.0.0、10.0.1.0、10.0.20.1、10.0.40.1、10.0.60.1、10.0.123.240、10.0.123.244、10.0.123.248。

R5 没有 Area 0 的具体信息，但是该区域的子网地址全部由路由器 R4 汇聚后以区域间链路的形式进行通告。

```
R2#show ip ospf database
OSPF Router with ID (10.0.20.1) (Process ID 48)
    Router Link States (Area 0)
Link ID      ADV Router      Age      Seq#      Checksum Link count
10.0.20.1    10.0.20.1    570      0x80000003 0x001086 5
10.0.30.1    10.0.30.1    560      0x80000004 0x004D7D 2
10.0.40.1    10.0.40.1    560      0x80000003 0x00A4D3 2
10.0.60.1    10.0.60.1    540      0x80000003 0x00D26B 2
10.0.123.245 10.0.123.245 558      0x80000004 0x001557 4

    Net Link States (Area 0)
Link ID      ADV Router      Age      Seq#      Checksum
10.0.123.245 10.0.123.245 558      0x80000002 0x00DDC2
10.0.123.251 10.0.60.1    540      0x80000003 0x008B20

    Summary Net Link States (Area 0)
Link ID      ADV Router      Age      Seq#      Checksum
10.1.0.0     10.0.40.1    560      0x80000002 0x00E310
10.1.1.0     10.0.40.1    1385     0x80000001 0x003FAA
10.1.50.1    10.0.40.1    1385     0x80000001 0x00BD03
```

图 27: R2 上 OSPF 数据库信息

```
R4#show ip ospf database
OSPF Router with ID (10.0.40.1) (Process ID 48)
    Router Link States (Area 0)
Link ID      ADV Router      Age      Seq#      Checksum Link count
10.0.20.1    10.0.20.1    565      0x80000003 0x001086 5
10.0.30.1    10.0.30.1    553      0x80000004 0x004D7D 2
10.0.40.1    10.0.40.1    553      0x80000003 0x00A4D3 2
10.0.60.1    10.0.60.1    534      0x80000003 0x00D26B 2
10.0.123.245 10.0.123.245 553      0x80000004 0x001557 4

    Net Link States (Area 0)
Link ID      ADV Router      Age      Seq#      Checksum
10.0.123.245 10.0.123.245 553      0x80000002 0x00DDC2
10.0.123.251 10.0.60.1    534      0x80000003 0x008B20

    Summary Net Link States (Area 0)
Link ID      ADV Router      Age      Seq#      Checksum
10.1.0.0      10.0.40.1    553      0x80000002 0x00E310
10.1.1.0      10.0.40.1    1378     0x80000001 0x003FAA
10.1.50.1     10.0.40.1    1378     0x80000001 0x00BD03

    Router Link States (Area 1)
Link ID      ADV Router      Age      Seq#      Checksum Link count
10.0.40.1    10.0.40.1    1392     0x80000002 0x00B0F8 1
10.0.50.1     10.0.50.1    1393     0x80000004 0x00EB32 3

    Net Link States (Area 1)
Link ID      ADV Router      Age      Seq#      Checksum
10.1.0.1      10.0.40.1    1393     0x80000001 0x00503A

    Summary Net Link States (Area 1)
Link ID      ADV Router      Age      Seq#      Checksum
10.0.0.0      10.0.40.1    564      0x80000002 0x00B828
10.0.1.0      10.0.40.1    565      0x80000003 0x0047A1
10.0.20.1     10.0.40.1    565      0x80000003 0x0011CC
10.0.40.1     10.0.40.1    565      0x80000002 0x00D103
10.0.60.1     10.0.40.1    565      0x80000002 0x00595D
10.0.123.240  10.0.40.1    565      0x80000003 0x00A6A3
10.0.123.244  10.0.40.1    565      0x80000002 0x00621B
10.0.123.248  10.0.40.1    566      0x80000004 0x00B9CB
```

图 28: R4 上 OSPF 数据库信息

```
R5#show ip ospf database
OSPF Router with ID (10.0.50.1) (Process ID 48)
Router Link States (Area 1)

Link ID      ADV Router      Age      Seq#      Checksum Link count
10.0.40.1    10.0.40.1    1374     0x80000002 0x00B0F8 1
10.0.50.1    10.0.50.1    1373     0x80000004 0x00EB32 3

Net Link States (Area 1)

Link ID      ADV Router      Age      Seq#      Checksum
10.1.0.1    10.0.40.1    1374     0x80000001 0x00503A

Summary Net Link States (Area 1)

Link ID      ADV Router      Age      Seq#      Checksum
10.0.0.0    10.0.40.1    544      0x80000002 0x00B828
10.0.1.0    10.0.40.1    544      0x80000003 0x0047A1
10.0.20.1   10.0.40.1    544      0x80000003 0x0011CC
10.0.40.1   10.0.40.1    544      0x80000002 0x00D103
10.0.60.1   10.0.40.1    544      0x80000002 0x00595D
10.0.123.240 10.0.40.1    544      0x80000003 0x00A6A3
10.0.123.244 10.0.40.1    544      0x80000002 0x00621B
10.0.123.248 10.0.40.1    561      0x80000004 0x0089CB
```

图 29: R5 上 OSPF 数据库信息

17. 分别在 R1、R5 上查看区域边界路由器 (ABR) 信息。

R1: 当前已知的区域 0 内的 ABR 的 IP 地址为 10.0.40.1，下一跳 IP 地址为 10.0.123.246。

R5: 当前已知的区域 1 内的 ABR 的 IP 地址为 10.0.40.1，下一跳 IP 地址为 10.1.0.1。

```
R1#show ip ospf border-routers
OSPF Process 48 internal Routing Table
Codes: i - Intra-area route, I - Inter-area route
i 10.0.40.1 [11] via 10.0.123.246, FastEthernet0/1, ABR, Area 0, SPF 4
```

图 30: R1 上 ABR 信息

```
R5#show ip ospf border-routers
OSPF Process 48 internal Routing Table
Codes: i - Intra-area route, I - Inter-area route
i 10.0.40.1 [10] via 10.1.0.1, FastEthernet0/1, ABR, Area 1, SPF 5
```

图 31: R5 上 ABR 信息

18. 给 R6 的 f0/1、R8 的各接口配置 IP 地址并激活，启用 OSPF 协议，各接口均属于 Area 2。配置 PC4 的 IP 地址和默认路由。过一会，查看 R8 上的路由表，标出 Area 1 的区域间路由，测试 PC4 与 PC1、PC3 的连通性。

R6 配置命令：

```

1 R6(config)#interface f0/1
2 R6(config-if)#ip address 10.2.0.1 255.255.255.0
3 R6(config-if)#no shutdown
4 R6(config)#router ospf 48
5 R6(config-router)#network 10.2.0.0 0.0.255.255 area 2

```

R8 配置命令：

```

1 R8(config)#interface f0/1
2 R8(config-if)#ip address 10.2.0.2 255.255.255.0
3 R8(config-if)#no shutdown
4 R8(config)#interface f0/0
5 R8(config-if)#ip address 10.2.2.1 255.255.255.0
6 R8(config-if)#no shutdown
7 R8(config)#interface f1/0
8 R8(config-if)#ip address 10.2.1.1 255.255.255.0
9 R8(config-if)#no shutdown
10 R8(config)#interface loopback 0
11 R8(config-if)#ip address 10.2.80.1 255.255.255.252
12 R8(config)#router ospf 48
13 R8(config-router)#network 10.2.0.0 0.0.255.255 area 2

```

PC4 配置命令：

```
1 PC4> ip 10.2.1.4 255.255.255.0 10.2.1.1
```

R8 的路由表：区域间路由包含了 Area 1 和 Area 0 的地址，其中 Area 1 的子网地址有 10.1.1.0、10.1.0.0、10.1.50.1。

```

R8#show ip route
Codes: 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

Gateway of last resort is not set

10.0.0.0/8 is variably subnetted, 15 subnets, 4 masks
C        10.2.0.0/24 is directly connected, FastEthernet0/1
C        10.2.1.0/24 is directly connected, FastEthernet1/0
C        10.2.2.0/24 is directly connected, FastEthernet0/0
O IA    10.1.1.0/24 [110/40] via 10.2.0.1, 00:02:33, FastEthernet0/1
O IA    10.0.0.0/24 [110/40] via 10.2.0.1, 00:02:33, FastEthernet0/1
O IA    10.1.0.0/24 [110/30] via 10.2.0.1, 00:02:33, FastEthernet0/1
O IA    10.0.1.0/24 [110/30] via 10.2.0.1, 00:02:33, FastEthernet0/1
O IA    10.0.20.1/32 [110/21] via 10.2.0.1, 00:02:35, FastEthernet0/1
O IA    10.0.40.1/32 [110/21] via 10.2.0.1, 00:02:35, FastEthernet0/1
O IA    10.0.60.1/32 [110/11] via 10.2.0.1, 00:02:35, FastEthernet0/1
O IA    10.1.50.1/32 [110/31] via 10.2.0.1, 00:02:35, FastEthernet0/1
C        10.2.80.0/30 is directly connected, Loopback0
O IA    10.0.123.240/30 [110/84] via 10.2.0.1, 00:02:36, FastEthernet0/1
O IA    10.0.123.244/30 [110/30] via 10.2.0.1, 00:02:37, FastEthernet0/1
O IA    10.0.123.248/29 [110/20] via 10.2.0.1, 00:02:37, FastEthernet0/1

```

图 32: R8 的路由表

```
[PC4]> ping 10.0.0.2
10.0.0.2 icmp_seq=1 timeout
10.0.0.2 icmp_seq=2 timeout
84 bytes from 10.0.0.2 icmp_seq=3 ttl=60 time=77.762 ms
84 bytes from 10.0.0.2 icmp_seq=4 ttl=60 time=71.266 ms
84 bytes from 10.0.0.2 icmp_seq=5 ttl=60 time=65.508 ms
```

图 33: PC4 能 ping 通 PC1

```
[PC4]> ping 10.1.1.3
10.1.1.3 icmp_seq=1 timeout
10.1.1.3 icmp_seq=2 timeout
84 bytes from 10.1.1.3 icmp_seq=3 ttl=60 time=88.707 ms
84 bytes from 10.1.1.3 icmp_seq=4 ttl=60 time=85.312 ms
84 bytes from 10.1.1.3 icmp_seq=5 ttl=60 time=91.005 ms
```

图 34: PC4 能 ping 通 PC2

19. 配置 Frame Relay 数据链路。

Port:DLCI	Port:DLCI
1:101	10:202
2:102	11:203

图 35: FR 交换机的虚链路配置表

20. 给 R5 的 s0/0 接口配置封装协议为 Frame Relay 并激活，然后创建 2 个子接口，配置其 IP 地址、接口 DLCI，配置 R5 的 s0/0 接口属于 Area 1。

R5 配置命令：

```

1 R5(config)#interface s0/0
2 R5(config-if)#encapsulation frame-relay
3 R5(config-if)#frame-relay lmi-type ANSI
4 R5(config-if)#no shutdown
5 R5(config-if)#interface s0/0.1 multipoint
6 R5(config-subif)#ip address 10.1.2.5 255.255.255.0
7 R5(config-subif)#frame-relay interface-dlci 101
8 R5(config-fr-dlci)#interface s0/0.2 multipoint
9 R5(config-subif)#ip address 10.1.2.6 255.255.255.0
10 R5(config-subif)#frame-relay interface-dlci 102
11 R5(config-fr-dlci)#exit
12 R5(config-subif)#exit
13 R5(config)#router ospf 48
```

14 R5(config-router)#network 10.1.2.0 0.0.0.255 area 1

21. 给 R7 的各接口配置 IP 地址、激活，其中回环接口和 f0/0 接口属于 Area 2，s0/0 接口属于 Area 1，配置 s0/0 封装协议为 Frame Relay，DLCI 值设为 Frame Relay 交换机上 R5-R7 之间数据链路的相关 DLCI 值。

R7 配置命令：

```

1 R7(config)#interface f0/0
2 R7(config-if)#ip address 10.2.2.2 255.255.255.0
3 R7(config-if)#no shutdown
4 R7(config-if)#interface s0/0
5 R7(config-if)#ip address 10.1.2.7 255.255.255.0
6 R7(config-if)#encapsulation frame-relay
7 R7(config-if)#frame-relay lmi-type ANSI
8 R7(config-if)#frame-relay interface-dlci 202
9 R7(config-fr-dlci)#exit
10 R7(config-if)#no shutdown
11 R7(config-if)#interface loopback 0
12 R7(config-if)#ip address 10.2.70.1 255.255.255.252
13 R7(config-if)#router ospf 48
14 R7(config-router)#network 10.2.0.0 0.0.255.255 area 2
15 R7(config-router)#network 10.1.0.0 0.0.255.255 area 1

```

在 R7 上查看 Frame Relay 映射：

```
[R7#show frame-relay map
Serial0/0 (up): ip 10.1.2.5 dlci 202(0xCA,0x30A0), dynamic,
broadcast,, status defined, active]
```

图 36: R7 上的 Frame Relay 映射

在 R5 上查看 Frame Relay 映射：

```
[R5#show frame-relay map
Serial0/0.1 (up): ip 10.1.2.7 dlci 101(0x65,0x1850), dynamic,
broadcast,, status defined, active]
```

图 37: R5 上的 Frame Relay 映射

在 R7 上测试到 R5 的连通性：

```
[R7#ping 10.1.2.5
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.1.2.5, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/16/68 ms]
```

图 38: R7 能 ping 通 R5

22. 给 R9 的各接口配置 IP 地址、激活，其中回环接口和 f0/1 接口属于 Area 3，s0/0 接口属于 Area 1，配置 s0/0 封装协议为 Frame Relay，DLCI 值设为 Frame Relay 交换机上 R5-R9 之间数据链路的相关 DLCI 值。

R9 配置命令：

```

1 R9(config)#interface f0/1
2 R9(config-if)#ip address 10.3.0.1 255.255.255.0
3 R9(config-if)#no shutdown
4 R9(config-if)#interface s0/0
5 R9(config-if)#ip address 10.1.2.9 255.255.255.0
6 R9(config-if)#encapsulation frame-relay
7 R9(config-if)#frame-relay lmi-type ANSI
8 R9(config-if)#frame-relay interface-dlci 203
9 R9(config-fr-dlci)#exit
10 R9(config-if)#no shutdown
11 R9(config-if)#interface loopback 0
12 R9(config-if)#ip address 10.3.90.1 255.255.255.252
13 R9(config-if)#router ospf 48
14 R9(config-router)#network 10.3.0.0 0.0.255.255 area 3
15 R9(config-router)#network 10.1.0.0 0.0.255.255 area 1

```

在 R9 上查看 Frame Relay 映射：

```
[R9#show frame-relay map
Serial0/0 (up): ip 10.1.2.6 dlci 203(0xCB,0x30B0), dynamic,
broadcast,, status defined, active]
```

图 39: R9 上的 Frame Relay 映射

在 R9 上测试到 R5 的连通性：

```
[R9#ping 10.1.2.6
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.1.2.6, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/9/36 ms]
```

图 40: R9 能 ping 通 R5

在 R9 上测试到 R5 的连通性：

```
[R9#ping 10.1.2.7
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.1.2.7, timeout is 2 seconds:
.....
Success rate is 0 percent (0/5)]
```

图 41: R9 不能 ping 通 R7

23. 分别在 R5、R7、R9 上查看 OSPF 邻居关系。

```
R5#show ip ospf neighbor
Neighbor ID      Pri   State          Dead Time     Address           Interface
10.0.40.1        1     FULL/BDR      00:00:38     10.1.0.1       FastEthernet0/1
```

图 42: R5 的 OSPF 邻居关系

```
R7#show ip ospf neighbor
Neighbor ID      Pri   State          Dead Time     Address           Interface
10.2.80.1        1     FULL/DR       00:00:35     10.2.2.1       FastEthernet0/0
```

图 43: R7 的 OSPF 邻居关系

```
R9#show ip ospf neighbor
```

图 44: R9 的 OSPF 邻居关系

24. 分别在 R5、R7、R9 上配置 s2/0 的接口为点对多点的网络类型，然后再次查看邻居关系。

R5 配置命令：

```
1 R5(config)#interface s0/0.1
2 R5(config-subif)#ip ospf network point-to-multipoint
3 R5(config)#interface s0/0.2
4 R5(config-subif)#ip ospf network point-to-multipoint
```

R7 配置命令：

```
1 R7(config)#interface s0/0
2 R7(config-subif)#ip ospf network point-to-multipoint
```

R9 配置命令：

```
1 R9(config)#interface s0/0
2 R9(config-subif)#ip ospf network point-to-multipoint
```

```
R5#show ip ospf neighbor
Neighbor ID      Pri   State          Dead Time     Address           Interface
10.0.40.1        1     FULL/BDR      00:00:39     10.1.0.1       FastEthernet0/1
10.3.90.1        0     FULL/ -       00:01:49     10.1.2.9       Serial0/0.2
10.2.70.1        0     FULL/ -       00:01:50     10.1.2.7       Serial0/0.1
```

图 45: R5 的 OSPF 邻居关系

R7#show ip ospf neighbor						
Neighbor ID	Pri	State	Dead Time	Address	Interface	
10.1.50.1	0	FULL/-	00:01:49	10.1.2.5	Serial0/0	
10.2.80.1	1	FULL/DR	00:00:37	10.2.2.1	FastEthernet0/0	

图 46: R7 的 OSPF 邻居关系

R9#show ip ospf neighbor						
Neighbor ID	Pri	State	Dead Time	Address	Interface	
10.1.50.1	0	FULL/-	00:01:40	10.1.2.6	Serial0/0	

图 47: R9 的 OSPF 邻居关系

25. 分别在 R5、R8、R7 上查看 OSPF 数据库，观察 Summary Net Link 部分。

R5 的 OSPF 数据库: Area 1 所有的的聚合路由都是由区域边界路由器 (ABR)10.0.40.1 宣告的，而 R7 作为 Area 1 和 Area 2 的 ABR，却没有向 Area 1 宣告 Area 2 的路由信息，是因为所有的 Area 都只和 Area 0 进行路由信息交换。

R8 的 OSPF 数据库: Area 2 所有的的聚合路由都是由区域边界路由器 (ABR)10.0.60.1 宣告的，而 R7 作为 Area 1 和 Area 2 的 ABR，也没有向 Area 2 宣告 Area 1 的路由信息。

R7 的 OSPF 数据库: Area 1 所有的的聚合路由都是由区域边界路由器 (ABR)10.0.40.1 宣告的，Area 2 所有的的聚合路由都是由区域边界路由器 (ABR)10.0.60.1 宣告的。

Summary Net Link States (Area 1)				
Link ID	ADV Router	Age	Seq#	Checksum
10.0.1.0	10.0.40.1	1885	0x80000001	0x004B9F
10.0.20.1	10.0.40.1	1885	0x80000001	0x0015CA
10.0.40.1	10.0.40.1	1927	0x80000001	0x00D302
10.0.60.1	10.0.40.1	1885	0x80000001	0x005B5C
10.0.123.244	10.0.40.1	1885	0x80000001	0x00641A
10.0.123.248	10.0.40.1	1944	0x80000001	0x00BFC8
10.2.0.0	10.0.40.1	1902	0x80000001	0x003EAB
10.2.1.0	10.0.40.1	1903	0x80000001	0x003DAA
10.2.2.0	10.0.40.1	1903	0x80000001	0x008C51
10.2.70.1	10.0.40.1	1894	0x80000001	0x009DF9
10.2.80.1	10.0.40.1	1903	0x80000001	0x00CAC0

图 48: R5 的 OSPF 数据库

Summary Net Link States (Area 2)				
Link ID	ADV Router	Age	Seq#	Checksum
10.0.1.0	10.0.60.1	1887	0x80000001	0x00BE18
10.0.20.1	10.0.60.1	1887	0x80000001	0x008843
10.0.40.1	10.0.60.1	1887	0x80000001	0x00AB0C
10.0.60.1	10.0.60.1	1927	0x80000001	0x006A43
[10.0.123.244]	10.0.60.1	1887	0x80000001	0x00D792
[10.0.123.248]	10.0.60.1	1970	0x80000001	0x003341
10.1.0.0	10.0.60.1	1931	0x80000001	0x00BD19
10.1.1.0	10.0.60.1	1921	0x80000001	0x0017B4
10.1.2.5	10.0.60.1	400	0x80000001	0x00755A
10.1.2.6	10.0.60.1	380	0x80000001	0x006B63
10.1.2.7	10.0.60.1	283	0x80000001	0x00E3A9
10.1.2.9	10.0.60.1	283	0x80000001	0x00CFBB
10.1.50.1	10.0.60.1	1921	0x80000001	0x00950D

图 49: R8 的 OSPF 数据库

Summary Net Link States (Area 1)				
Link ID	ADV Router	Age	Seq#	Checksum
10.0.1.0	10.0.40.1	1887	0x80000001	0x004B9F
10.0.20.1	10.0.40.1	1887	0x80000001	0x0015CA
10.0.40.1	10.0.40.1	1929	0x80000001	0x00D302
10.0.60.1	10.0.40.1	1887	0x80000001	0x005B5C
[10.0.123.244]	10.0.40.1	1887	0x80000001	0x00641A
[10.0.123.248]	10.0.40.1	1993	0x80000001	0x00BFC8
10.2.0.0	10.0.40.1	1951	0x80000001	0x003EAB
10.2.1.0	10.0.40.1	1951	0x80000001	0x003DAA
10.2.2.0	10.0.40.1	1951	0x80000001	0x008C51
10.2.70.1	10.0.40.1	1943	0x80000001	0x009DF9
10.2.80.1	10.0.40.1	1951	0x80000001	0x00CAC

Router Link States (Area 2)				
Link ID	ADV Router	Age	Seq#	Checksum
10.0.60.1	10.0.60.1	1953	0x80000002	0x006519
10.2.70.1	10.2.70.1	1953	0x80000002	0x00F10D
10.2.80.1	10.2.80.1	1954	0x80000003	0x008AD2

Net Link States (Area 2)				
Link ID	ADV Router	Age	Seq#	Checksum
10.2.0.2	10.2.80.1	1	0x80000002	0x00B1E
10.2.2.1	10.2.80.1	3	0x80000002	0x009982

Summary Net Link States (Area 2)				
Link ID	ADV Router	Age	Seq#	Checksum
10.0.1.0	10.0.60.1	1957	0x80000001	0x00BE18
10.0.20.1	10.0.60.1	1958	0x80000001	0x008843
10.0.40.1	10.0.60.1	1958	0x80000001	0x00AB0C
10.0.60.1	10.0.60.1	1998	0x80000001	0x006A43
[10.0.123.244]	10.0.60.1	1959	0x80000001	0x00D792
[10.0.123.248]	10.0.60.1	1998	0x80000001	0x003341
10.1.0.0	10.0.60.1	1959	0x80000001	0x00BD19
10.1.1.0	10.0.60.1	1949	0x80000001	0x0017B4
10.1.2.5	10.0.60.1	428	0x80000001	0x00755A
10.1.2.6	10.0.60.1	408	0x80000001	0x006B63
10.1.2.7	10.0.60.1	311	0x80000001	0x00E3A9
10.1.2.9	10.0.60.1	311	0x80000001	0x00CFBB
10.1.50.1	10.0.60.1	1949	0x80000001	0x00950D

图 50: R7 的 OSPF 数据库

26. 在 R8 上查看去往 PC3 所在网络的路由信息。

前往子网 10.1.1.0 的下一跳 IP 地址是 10.0.60.1，是路由器 R6。

```
R8#show ip route 10.1.1.0
Routing entry for 10.1.1.0/24
Known via "ospf 48", distance 110, metric 40, type inter area
Last update from 10.2.0.1 on FastEthernet0/1, 00:38:49 ago
Routing Descriptor Blocks:
* 10.2.0.1, from 10.0.60.1, 00:38:49 ago, via FastEthernet0/1
  Route metric is 40, traffic share count is 1
```

图 51: R8 上去往 PC3 所在网络的路由信息

27. 断开路由器 R6 的 f0/0 接口，等候片刻，在 R8 上再次查看路由信息。

前往子网 10.1.1.0 的路由已经不存在。

```
[R8#show ip route 10.1.1.0
% Subnet not in table
```

图 52: 断开 R6 后 R8 上去往 PC3 所在网络的路由信息

R7 前往子网 10.1.1.0 的路由是存在的，但是由于 Area 2 和 Area 1 不直接交换路由信息，R7 没有向 Area 2 宣告路由的存在。

```
R7#show ip route 10.1.1.0
Routing entry for 10.1.1.0/24
Known via "ospf 48", distance 110, metric 74, type intra area
Last update from 10.1.2.5 on Serial0/0, 00:15:36 ago
Routing Descriptor Blocks:
* 10.1.2.5, from 10.1.50.1, 00:15:36 ago, via Serial0/0
  Route metric is 74, traffic share count is 1
```

图 53: R7 上去往 PC3 所在网络的路由信息

重新打开 R6 的 f0/0 接口，R8 的路由信息恢复。

```
[R8#show ip route 10.1.1.0
Routing entry for 10.1.1.0/24
Known via "ospf 48", distance 110, metric 40, type inter area
Last update from 10.2.0.1 on FastEthernet0/1, 00:00:18 ago
Routing Descriptor Blocks:
* 10.2.0.1, from 10.0.60.1, 00:00:18 ago, via FastEthernet0/1
  Route metric is 40, traffic share count is 1
```

图 54: 恢复 R6 后 R8 上去往 PC3 所在网络的路由信息

28. 给 R10 的 f0/0、f0/1 接口配置 IP 地址并激活，启用 OSPF 协议，各接口均属于 Area 3。配置 PC5 的 IP 地址和默认路由。过一会，查看 R10 上的路由表和 OSPF 数据库。

R10 配置命令：

```

1 R10(config)#interface f0/1
2 R10(config-if)#ip address 10.3.0.2 255.255.255.0
3 R10(config-if)#no shutdown
4 R10(config)#interface f0/0
5 R10(config-if)#ip address 10.3.1.1 255.255.255.0
6 R10(config-if)#no shutdown
7 R10(config-if)#interface loopback 0
8 R10(config-if)#ip address 10.3.100.1 255.255.255.252
9 R10(config-if)#router ospf 48
10 R10(config-router)#network 10.3.0.0 0.0.255.255 area 3

```

R10 的 OSPF 数据库：数据库中没有其他 Area 的信息，因为 Area 3 和 Area 1 不直接交换信息。

```

R10#show ip ospf database
OSPF Router with ID (10.3.100.1) (Process ID 48)
Router Link States (Area 3)
Link ID      ADV Router     Age      Seq#      Checksum Link count
10.3.90.1    10.3.90.1    19       0x80000005 0x00E0DE 2
10.3.100.1   10.3.100.1   13       0x80000002 0x0098E2 3
Net Link States (Area 3)
Link ID      ADV Router     Age      Seq#      Checksum
10.3.0.1     10.3.90.1    19       0x80000001 0x004D9B

```

图 55: R10 的 OSPF 数据库

R10 的路由表：路由表中没有其他 Area 的信息，因为 OSPF 数据库中缺乏相关数据。

```

R10#show ip route
Codes: 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
Gateway of last resort is not set

      10.0.0.0/8 is variably subnetted, 4 subnets, 3 masks
C        10.3.1.0/24 is directly connected, FastEthernet0/0
C        10.3.0.0/24 is directly connected, FastEthernet0/1
O        10.3.90.1/32 [110/11] via 10.3.0.1, 00:01:26, FastEthernet0/1
C        10.3.100.0/30 is directly connected, Loopback0

```

图 56: R10 的路由表

29. 在 Area 1 上的两个边界路由器 R9、R4 之间为 Area 3 和 Area 0 创建虚链路。稍后查看虚链路建立情况和邻居信息。

R4 配置命令：

```

1 R4(config)#router ospf 48
2 R4(config-router)#router-id 10.0.40.1
3 R4(config-router)#area 1 virtual-link 10.3.90.1

```

R9 配置命令：

```

1 R9(config)#router ospf 48
2 R9(config-router)#router-id 10.3.90.1
3 R9(config-router)#area 1 virtual-link 10.0.40.1

```

R4 虚链路：R4 通过区域 1 的接口 FastEthernet0/1 与 R9（RID 是 10.3.90.1）建立了虚链路，使用的 Cost 值为 74。

R9 虚链路：R9 通过区域 1 的接口 Serial0/0 与 R4（RID 是 10.0.40.1）建立了虚链路，使用的 Cost 值为 74。

R4 邻居信息：R4 通过接口 OSPF_VL0 与 R9（RID 是 10.3.90.1）建立了邻接关系。

R9 邻居信息：R9 通过接口 OSPF_VL0 与 R4（RID 是 10.0.40.1）建立了邻接关系。

```

[R4]#show ip ospf virtual-links
Virtual Link OSPF_VL0 to router 10.3.90.1 is up
Run as demand circuit
DoNotAge LSA allowed.
Transit area 1, via interface FastEthernet0/1, Cost of using 74
Transmit Delay is 1 sec, State POINT_TO_POINT,
Timer intervals configured, Hello 10, Dead 40, Wait 40, Retransmit 5
Hello due in 00:00:07
Adjacency State FULL (Hello suppressed)
Index 4/5, retransmission queue length 0, number of retransmission 0
First 0x0(0)/0x0(0) Next 0x0(0)/0x0(0)
Last retransmission scan length is 0, maximum is 0
Last retransmission scan time is 0 msec, maximum is 0 msec

```

图 57: R4 虚链路

```

[R9]#show ip ospf virtual-links
Virtual Link OSPF_VL0 to router 10.0.40.1 is up
Run as demand circuit
DoNotAge LSA allowed.
Transit area 1, via interface Serial0/0, Cost of using 74
Transmit Delay is 1 sec, State POINT_TO_POINT,
Timer intervals configured, Hello 10, Dead 40, Wait 40, Retransmit 5
Hello due in 00:00:01
Adjacency State FULL (Hello suppressed)
Index 1/3, retransmission queue length 0, number of retransmission 0
First 0x0(0)/0x0(0) Next 0x0(0)/0x0(0)
Last retransmission scan length is 0, maximum is 0
Last retransmission scan time is 0 msec, maximum is 0 msec

```

图 58: R9 虚链路

Neighbor ID	Pri	State	Dead Time	Address	Interface
10.3.90.1	0	FULL/-	-	10.1.2.9	OSPF_VL0
10.0.20.1	1	FULL/DROTHER	00:00:30	10.0.123.249	FastEthernet0/0
10.0.30.1	1	FULL/BDR	00:00:30	10.0.123.250	FastEthernet0/0
10.0.60.1	1	FULL/DROTHER	00:00:31	10.0.123.251	FastEthernet0/0
10.1.50.1	1	FULL/DR	00:00:38	10.1.0.2	FastEthernet0/1

图 59: R4 邻居信息

R9#show ip ospf neighbor					
Neighbor ID	Pri	State	Dead Time	Address	Interface
10.0.40.1	0	FULL/ -	-	10.1.0.1	OSPF_VL0
10.1.50.1	0	FULL/ -	00:01:54	10.1.2.6	Serial0/0
10.3.100.1	1	FULL/BDR	00:00:32	10.3.0.2	FastEthernet0/1

图 60: R9 邻居信息

30. 显示 R10 的路由表和 OSPF 数据库，标出 PC1、PC2、PC3 所在的子网相关记录。

所有其他区域路由信息均由区域边界路由器 R9 宣告。

R10# show ip route					
O IA	10.0.0.0/8	is variably subnetted, 24 subnets, 4 masks	R1#	ULL,	*Mar
C	10.1.2.9/32	[110/10]	via 10.3.0.1, 00:00:23, FastEthernet0/1	ULL,	
C	10.3.1.0/24	is directly connected, FastEthernet0/0		ULL,	
O IA	10.2.0.0/24	[110/104]	via 10.3.0.1, 00:00:13, FastEthernet0/1	R6#	
C	10.3.0.0/24	is directly connected, FastEthernet0/1			
O IA	10.2.1.0/24	[110/105]	via 10.3.0.1, 00:00:13, FastEthernet0/1		
O IA	10.2.2.0/24	[110/114]	via 10.3.0.1, 00:00:13, FastEthernet0/1		
O IA	10.1.1.0/24	[110/84]	via 10.3.0.1, 00:00:23, FastEthernet0/1		
O IA	10.0.0.0/24	[110/114]	via 10.3.0.1, 00:00:15, FastEthernet0/1		
O IA	10.1.0.0/24	[110/84]	via 10.3.0.1, 00:00:24, FastEthernet0/1		
O IA	10.0.1.0/24	[110/104]	via 10.3.0.1, 00:00:15, FastEthernet0/1		
O IA	10.1.2.5/32	[110/74]	via 10.3.0.1, 00:00:24, FastEthernet0/1		
O IA	10.1.2.7/32	[110/138]	via 10.3.0.1, 00:00:24, FastEthernet0/1		
O IA	10.1.2.6/32	[110/74]	via 10.3.0.1, 00:00:26, FastEthernet0/1		
O IA	10.0.20.1/32	[110/95]	via 10.3.0.1, 00:00:17, FastEthernet0/1		
O IA	10.0.40.1/32	[110/85]	via 10.3.0.1, 00:00:17, FastEthernet0/1		
O IA	10.0.60.1/32	[110/95]	via 10.3.0.1, 00:00:17, FastEthernet0/1		
O IA	10.1.50.1/32	[110/75]	via 10.3.0.1, 00:00:27, FastEthernet0/1		
O IA	10.2.70.1/32	[110/115]	via 10.3.0.1, 00:00:17, FastEthernet0/1		
O	10.3.90.1/32	[110/11]	via 10.3.0.1, 00:00:28, FastEthernet0/1		
O IA	10.2.80.1/32	[110/105]	via 10.3.0.1, 00:00:18, FastEthernet0/1		
C	10.3.100.0/30	is directly connected, Loopback0			
O IA	10.0.123.240/30	[110/158]	via 10.3.0.1, 00:00:19, FastEthernet0/1		
O IA	10.0.123.244/30	[110/104]	via 10.3.0.1, 00:00:19, FastEthernet0/1		
O IA	10.0.123.248/29	[110/94]	via 10.3.0.1, 00:00:20, FastEthernet0/1		

图 61: R10 的路由表

Summary Net Link States (Area 3)				
Link ID	ADV Router	Age	Seq#	Checksum
10.0.0.0	10.3.90.1	55	0x80000001	0x002A38
10.0.1.0	10.3.90.1	55	0x80000001	0x00BAB0
10.0.20.1	10.3.90.1	55	0x80000001	0x0084DB
10.0.40.1	10.3.90.1	55	0x80000001	0x004313
10.0.60.1	10.3.90.1	55	0x80000001	0x00CA6D
10.0.123.240	10.3.90.1	55	0x80000001	0x001AB2
10.0.123.244	10.3.90.1	55	0x80000001	0x00D32B
10.0.123.248	10.3.90.1	58	0x80000001	0x002FD9
10.1.0.0	10.3.90.1	74	0x80000001	0x00F08E
10.1.1.0	10.3.90.1	74	0x80000001	0x00E598
10.1.2.5	10.3.90.1	74	0x80000001	0x00443E
10.1.2.6	10.3.90.1	74	0x80000001	0x003A47
10.1.2.7	10.3.90.1	74	0x80000001	0x00B28D
10.1.2.9	10.3.90.1	74	0x80000001	0x009925
10.1.50.1	10.3.90.1	74	0x80000001	0x0064F0
10.2.0.0	10.3.90.1	59	0x80000001	0x00ADBC
10.2.1.0	10.3.90.1	60	0x80000001	0x00ACBB
10.2.2.0	10.3.90.1	60	0x80000001	0x00FB62
10.2.70.1	10.3.90.1	60	0x80000001	0x000D0B
10.2.80.1	10.3.90.1	60	0x80000001	0x003ADD

图 62: R10 的 OSPF 数据库

31. 在 R9 上手工合并 Area 0 上的子网路由，然后显示 R9 和 R10 的路由表，查看所指定的子网是否合并了路由。

R9 配置命令：

```

1 R9(config)#router ospf 48
2 R9(config-router)#area 0 range 10.0.0.0 255.255.0.0

```

R9 的路由表：标出合并的那条路由，这条路由采用了特殊的接口 Null0 作为下一跳。

R10 的路由表：标出合并的那条路由，这条路由下一跳的 IP 地址是 10.3.0.1，是路由器 R9 的接口。

```

        10.0.0.0/8 is variably subnetted, 25 subnets, 5 masks
O      10.3.1.0/24 [110/20] via 10.3.0.2, 00:01:19, FastEthernet0/1
O IA    10.2.0.0/24 [110/94] via 10.1.2.6, 00:01:19, Serial0/0
C      10.3.0.0/24 is directly connected, FastEthernet0/1
O IA    10.2.1.0/24 [110/95] via 10.1.2.6, 00:01:19, Serial0/0
C      10.1.2.0/24 is directly connected, Serial0/0
O IA    10.2.2.0/24 [110/104] via 10.1.2.6, 00:01:19, Serial0/0
O      10.1.1.0/24 [110/74] via 10.1.2.6, 00:01:19, Serial0/0
O      10.0.0.0/24 [110/104] via 10.1.2.6, 00:01:20, Serial0/0
O      10.0.0.0/16 is a summary, 00:01:20, Null0
O      10.1.0.0/24 [110/74] via 10.1.2.6, 00:01:20, Serial0/0
O      10.0.1.0/24 [110/94] via 10.1.2.6, 00:01:20, Serial0/0
O      10.1.2.5/32 [110/64] via 10.1.2.6, 00:01:20, Serial0/0
[O     10.1.2.7/32 [110/128] via 10.1.2.6, 00:01:29, Serial0/0
[O     10.1.2.6/32 [110/64] via 10.1.2.6, 00:01:29, Serial0/0
[O     10.0.20.1/32 [110/85] via 10.1.2.6, 00:01:29, Serial0/0
[O     10.0.40.1/32 [110/75] via 10.1.2.6, 00:01:29, Serial0/0
[O     10.0.60.1/32 [110/85] via 10.1.2.6, 00:01:29, Serial0/0
[O     10.1.50.1/32 [110/65] via 10.1.2.6, 00:01:30, Serial0/0
O IA    10.2.70.1/32 [110/105] via 10.1.2.6, 00:01:30, Serial0/0
C      10.3.90.0/30 is directly connected, Loopback0
O IA    10.2.80.1/32 [110/95] via 10.1.2.6, 00:01:30, Serial0/0
O      10.3.100.1/32 [110/11] via 10.3.0.2, 00:01:30, FastEthernet0/1
O      10.0.123.240/30 [110/148] via 10.1.2.6, 00:01:30, Serial0/0
O      10.0.123.244/30 [110/94] via 10.1.2.6, 00:01:30, Serial0/0
[O     10.0.123.248/29 [110/84] via 10.1.2.6, 00:01:30, Serial0/0

```

图 63: R9 的路由表

```

        10.0.0.0/8 is variably subnetted, 17 subnets, 4 masks
O IA    10.1.2.9/32 [110/10] via 10.3.0.1, 00:14:20, FastEthernet0/1
C      10.3.1.0/24 is directly connected, FastEthernet0/0
O IA    10.2.0.0/24 [110/104] via 10.3.0.1, 00:14:11, FastEthernet0/1
C      10.3.0.0/24 is directly connected, FastEthernet0/1
O IA    10.2.1.0/24 [110/105] via 10.3.0.1, 00:14:11, FastEthernet0/1
O IA    10.2.2.0/24 [110/114] via 10.3.0.1, 00:14:11, FastEthernet0/1
O IA    10.1.1.0/24 [110/84] via 10.3.0.1, 00:14:21, FastEthernet0/1
O IA    10.0.0.0/16 [110/85] via 10.3.0.1, 00:01:28, FastEthernet0/1
O IA    10.1.0.0/24 [110/84] via 10.3.0.1, 00:14:21, FastEthernet0/1
O IA    10.1.2.5/32 [110/74] via 10.3.0.1, 00:14:21, FastEthernet0/1
O IA    10.1.2.7/32 [110/138] via 10.3.0.1, 00:14:21, FastEthernet0/1
O IA    10.1.2.6/32 [110/74] via 10.3.0.1, 00:14:21, FastEthernet0/1
O IA    10.1.50.1/32 [110/75] via 10.3.0.1, 00:15:21, FastEthernet0/1
O IA    10.2.70.1/32 [110/115] via 10.3.0.1, 00:15:12, FastEthernet0/1
O      10.3.90.1/32 [110/11] via 10.3.0.1, 00:15:22, FastEthernet0/1
O IA    10.2.80.1/32 [110/105] via 10.3.0.1, 00:15:12, FastEthernet0/1
C      10.3.100.0/30 is directly connected, Loopback0

```

图 64: R10 的路由表

32. 整理各路由器的当前运行配置，选择与本实验相关的内容记录在文本文件中

R1.txt

```

1 R1#show running-config
2 !
3 hostname R1
4 !
5 interface FastEthernet0/0
6   ip address 10.0.0.1 255.255.255.0
7   duplex auto

```

```
8 speed auto
9 !
10 interface Serial0/0
11 ip address 10.0.123.241 255.255.255.252
12 clock rate 128000
13 !
14 interface FastEthernet0/1
15 ip address 10.0.123.245 255.255.255.252
16 duplex auto
17 speed auto
18 !
19 router ospf 48
20 log-adjacency-changes
21 network 10.0.0.0 0.0.255.255 area 0
22 !
23 router rip
24 version 2
25 network 10.0.0.0
26 !
27 end
```

R2.txt

```
1 R2#show running-config
2 !
3 hostname R2
4 !
5 interface Loopback0
6 ip address 10.0.20.1 255.255.255.252
7 !
8 interface FastEthernet0/0
9 ip address 10.0.1.1 255.255.255.0
10 duplex auto
11 speed auto
12 !
13 interface Serial0/0
14 ip address 10.0.123.242 255.255.255.252
15 clock rate 2000000
16 !
17 interface FastEthernet1/0
18 ip address 10.0.123.249 255.255.255.248
19 duplex auto
20 speed auto
21 !
22 router ospf 48
23 log-adjacency-changes
24 network 10.0.0.0 0.0.255.255 area 0
25 !
26 router rip
27 version 2
```

```
28 network 10.0.0.0
29 !
30 end
```

R3.txt

```
1 R3#show running-config
2 !
3 hostname R3
4 !
5 interface FastEthernet0/1
6 ip address 10.0.123.246 255.255.255.252
7 duplex auto
8 speed auto
9 !
10 interface FastEthernet1/0
11 ip address 10.0.123.250 255.255.255.248
12 duplex auto
13 speed auto
14 !
15 router ospf 48
16 router-id 10.0.30.1
17 log-adjacency-changes
18 network 10.0.0.0 0.0.255.255 area 0
19 !
20 router rip
21 version 2
22 network 10.0.0.0
23 !
24 end
```

R4.txt

```
1 R4#show running-config
2 !
3 hostname R4
4 !
5 interface Loopback0
6 ip address 10.0.40.1 255.255.255.252
7 !
8 interface FastEthernet0/0
9 ip address 10.0.123.252 255.255.255.248
10 duplex auto
11 speed auto
12 !
13 interface FastEthernet0/1
14 ip address 10.1.0.1 255.255.255.0
15 duplex auto
16 speed auto
17 !
```

```
18 router ospf 48
19 router-id 10.0.40.1
20 log-adjacency-changes
21 area 1 virtual-link 10.3.90.1
22 network 10.0.0.0 0.0.255.255 area 0
23 network 10.1.0.0 0.0.255.255 area 1
24 !
25 end
```

R5.txt

```
1 R5#show running-config
2 !
3 hostname R5
4 !
5 interface Loopback0
6 ip address 10.1.50.1 255.255.255.252
7 !
8 interface FastEthernet0/0
9 ip address 10.1.1.1 255.255.255.0
10 duplex auto
11 speed auto
12 !
13 interface Serial0/0.1 multipoint
14 ip address 10.1.2.5 255.255.255.0
15 ip ospf network point-to-multipoint
16 frame-relay interface-dlci 101
17 !
18 interface Serial0/0.2 multipoint
19 ip address 10.1.2.6 255.255.255.0
20 ip ospf network point-to-multipoint
21 frame-relay interface-dlci 102
22 !
23 interface FastEthernet0/1
24 ip address 10.1.0.2 255.255.255.0
25 duplex auto
26 speed auto
27 !
28 router ospf 48
29 log-adjacency-changes
30 network 10.0.0.0 0.0.255.255 area 1
31 network 10.1.2.0 0.0.0.255 area 1
32 network 10.1.0.0 0.0.255.255 area 1
33 !
34 end
```

R6.txt

```
1 R6#show running-config
2 !
```

```
3 hostname R6
4 !
5 interface Loopback0
6 ip address 10.0.60.1 255.255.255.252
7 !
8 interface FastEthernet0/0
9 ip address 10.0.123.251 255.255.255.248
10 duplex auto
11 speed auto
12 !
13 interface FastEthernet0/1
14 ip address 10.2.0.1 255.255.255.0
15 duplex auto
16 speed auto
17 !
18 router ospf 48
19 router-id 10.0.60.1
20 log-adjacency-changes
21 network 10.0.0.0 0.0.255.255 area 0
22 network 10.2.0.0 0.0.255.255 area 2
23 !
24 end
```

R7.txt

```
1 R7#show running-config
2 !
3 hostname R7
4 !
5 interface Loopback0
6 ip address 10.2.70.1 255.255.255.252
7 !
8 interface FastEthernet0/0
9 ip address 10.2.2.2 255.255.255.0
10 duplex auto
11 speed auto
12 !
13 interface Serial0/0
14 ip address 10.1.2.7 255.255.255.0
15 encapsulation frame-relay
16 ip ospf network point-to-multipoint
17 clock rate 2000000
18 frame-relay interface-dlci 202
19 frame-relay lmi-type ansi
20 !
21 router ospf 48
22 log-adjacency-changes
23 network 10.1.0.0 0.0.255.255 area 1
24 network 10.2.0.0 0.0.255.255 area 2
25 !
```

26 end

R8.txt

```
1 R8#show running-config
2 !
3 hostname R8
4 !
5 interface Loopback0
6 ip address 10.2.80.1 255.255.255.252
7 !
8 interface FastEthernet0/0
9 ip address 10.2.2.1 255.255.255.0
10 duplex auto
11 speed auto
12 !
13 interface FastEthernet0/1
14 ip address 10.2.0.2 255.255.255.0
15 duplex auto
16 speed auto
17 !
18 interface FastEthernet1/0
19 ip address 10.2.1.1 255.255.255.0
20 duplex auto
21 speed auto
22 !
23 router ospf 48
24 log-adjacency-changes
25 network 10.2.0.0 0.0.255.255 area 2
26 !
27 end
```

R9.txt

```
1 R9#show running-config
2 !
3 hostname R9
4 !
5 interface Loopback0
6 ip address 10.3.90.1 255.255.255.252
7 !
8 interface Serial0/0
9 ip address 10.1.2.9 255.255.255.0
10 encapsulation frame-relay
11 ip ospf network point-to-multipoint
12 clock rate 2000000
13 frame-relay interface-dlci 203
14 frame-relay lmi-type ansi
15 !
16 interface FastEthernet0/1
```

```
17 ip address 10.3.0.1 255.255.255.0
18 duplex auto
19 speed auto
20 !
21 router ospf 48
22 router-id 10.3.90.1
23 log-adjacency-changes
24 area 0 range 10.0.0.0 255.255.0.0
25 area 1 virtual-link 10.0.40.1
26 network 10.1.0.0 0.0.255.255 area 1
27 network 10.3.0.0 0.0.255.255 area 3
28 !
29 end
```

R10.txt

```
1 R10#show running-config
2 !
3 hostname R10
4 !
5 interface Loopback0
6 ip address 10.3.100.1 255.255.255.252
7 !
8 interface FastEthernet0/0
9 ip address 10.3.1.1 255.255.255.0
10 duplex auto
11 speed auto
12 !
13 interface FastEthernet0/1
14 ip address 10.3.0.2 255.255.255.0
15 duplex auto
16 speed auto
17 !
18 router ospf 48
19 log-adjacency-changes
20 network 10.3.0.0 0.0.255.255 area 3
21 !
22 end
```

六、 实验结果与分析

1. 在一个网络中各路由器的 OSPF 进程号是否一定要相同？一个路由器上可配置多个进程号吗？

不一定要相同，进程号是路由器“私有的”，不同路由器之间不会相互干扰。一个路由器上可以配置多个进程号。

2. 未手工指定 Router ID 时，如果没有给回环接口配置 IP 地址，会从哪一个接口选取地址作为 Router ID？如果给回环接口配置了 IP 地址，又会从哪一个接口选取地址作为 Router ID？

如果没有给回环接口配置 IP 地址，会选择路由器上数值最大的 IP 地址作为此路由器的 Router ID，不考虑接口的 up/down 状态；如果给回环接口配置了 IP 地址，会选择回环接口作为 Router ID。

3. 如果 Router ID 对应的接口 down 了，路由器会自动重新选择另一个接口地址作为新的 Router ID 吗？

当且仅当被选为 Router ID 的接口 IP 地址被删除或修改时，才触发重新选择过程。其他情况包括接口 down 了，都不触发重新选择的过程。

4. 宣告网络属于哪个 area 的命令中，网络地址后面的参数是子网掩码吗？为什么要写成 0.0.255.255，而不是 255.255.0.0？

不是子网掩码，而是通配符掩码。在通配符掩码中，为 1 的位表示不需要检查，为 0 的位表示需要检查。通配符掩码为 0.0.255.255，表示前 16 位必须匹配，后 16 位无关。

5. 是不是所有其他 Area 上的路由器都只和 Area 0 上的路由器进行路由信息交换？虚链路的作用是什么？

是，在 OSPF 中非 Area 0 区域的路由信息相互间不能直接传递，都要通过 Area 0 来交换。虚链路的作用是将没有与 Area 0 物理连接的区域虚拟连接到 Area 0 上，实现区域间路由信息的传播。

6. 为什么要在区域边界路由器上进行路由合并？

进行路由合并，可以使路由表以更简短的规则来记录路由信息，便于维护。

七、讨论与心得

在本次实验过程中，当做到后面的步骤时，我遇到了一个很严重的问题，总会有一个路由器会“掉电”。反复重启 GNS3 和虚拟机都未能解决这一问题。后来，我将所有设备一个一个手动启动，发现启动到最后一个路由器时，会出现内存不够的警告信息。原本只分配了 2G 的内存，但这无法满足本实验 10 个路由器的配置。在 VMware 中调整虚拟机的内存大小，**分配较大的内存空间**，问题得以解决。由于这一故障，我在实验过程中浪费了大量的时间在重启模拟器上。但这也给我以启示，当出现所谓的“玄学” bug 时，不应盲目地反复重启，而要想办法进行深入的分析，找到原因所在，再进行有针对性的排除。