浙江大学

本科实验报告

课程名称：计算机网络基础

实验名称：动态路由协议 OSPF 配置

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浙江大学实验报告

一、 实验目的

1. 理解链路状态路由协议的工作原理。
2. 理解 OSPF 协议的工作机制。
3. 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、路由器、Console 连接线、直联网络线、交叉网络线（如果物理设备不足，可以使用模拟软件）。

四、 操作方法与实验步骤

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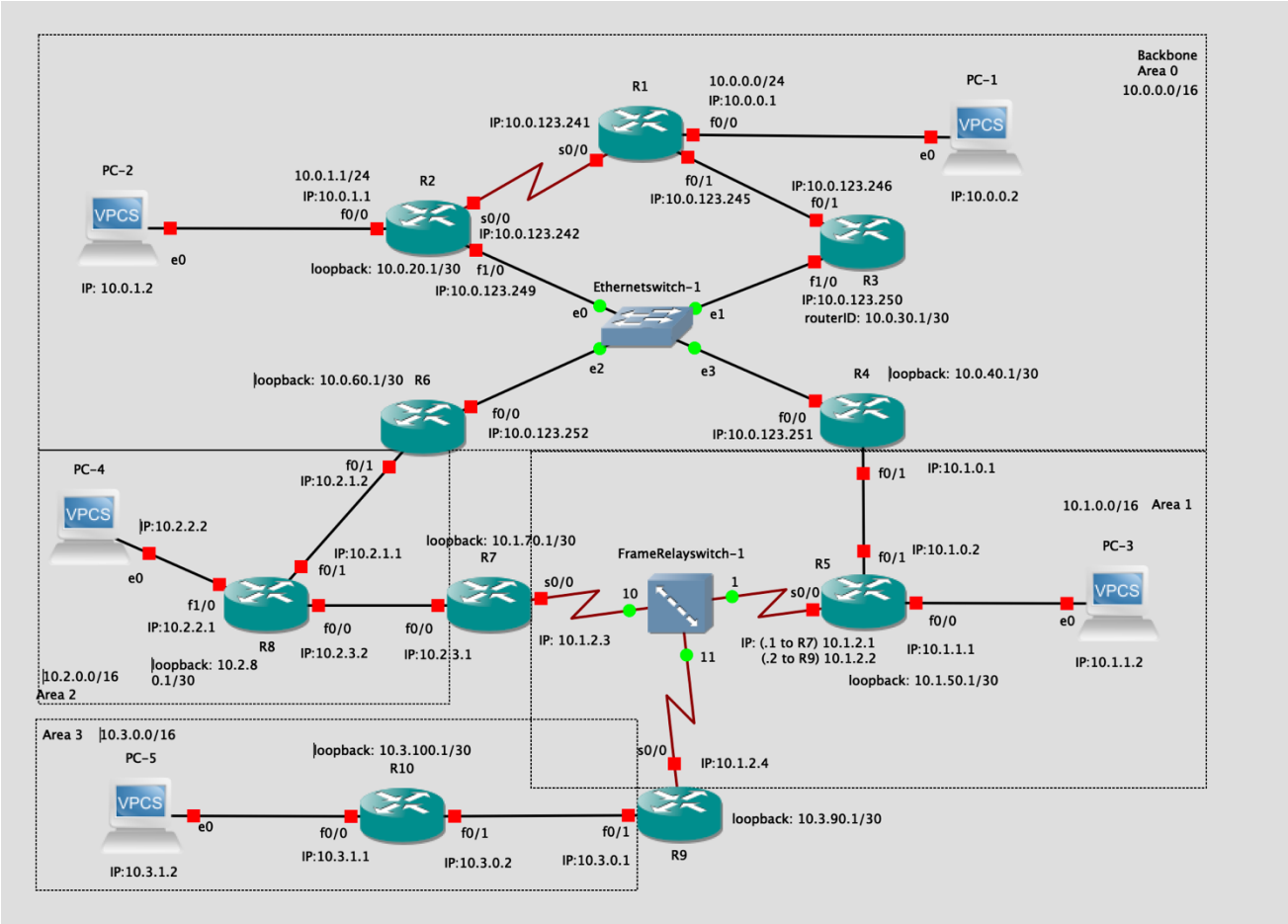
五、 实验数据记录和处理

以下实验记录需结合屏幕截图进行文字标注和描述，图片应大小合适、关键部分清晰可见（本文档中的截图仅用于示例，请更换成你自己的）。记录输入的命令时，直接粘帖文字即可（保留命令前面的提示符，如 R1#）。

1. 参考实验操作方法的说明，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。

设计的拓扑图（参考 GNS3 指南，在 FrameRelay 交换机上配置 R5-R7，R5-R9 之间的数据链路，每路由器 1 个物理端口）：



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（此处为截图形式，请使用文本形式，下同）：

```
R1(config)#int f0/0
R1(config-if)#ip addr 10.0.0.1 255.255.255.0
R1(config-if)#no shut
R1(config-if)#exit

R1(config)#int f0/1
R1(config-if)#ip addr 10.0.123.245 255.255.255.252
R1(config-if)#no shut
R1(config-if)#exit
```

```
R1(config)#int s0/0
R1(config-if)#ip addr 10.0.123.241 255.255.255.252
R1(config-if)#encapsu hdlc
R1(config-if)#clock rate 128000
R1(config-if)#no shut
R1(config-if)#exit
```

R2 配置命令：

```
R2(config)#int f0/0
R2(config-if)#ip addr 10.0.1.1 255.255.255.0
R2(config-if)#no shut
R2(config-if)#exit

R2(config)#int f1/0
R2(config-if)#ip addr 10.0.123.249 255.255.255.248
R2(config-if)#no shut
R2(config-if)#exit

R2(config)#int s0/0
R2(config-if)#ip addr 10.0.123.242 255.255.255.252
R2(config-if)#encapsu hdlc
R2(config-if)#no shut
R2(config-if)#exit
```

R3 配置命令：

```
R3(config)#int f0/1
R3(config-if)#ip addr 10.0.123.246 255.255.255.252
R3(config-if)#no shut
R3(config-if)#exit

R3(config)#int f1/0
R3(config-if)#ip addr 10.0.123.250 255.255.255.248
R3(config-if)#no shut
R3(config-if)#exit
```

Ping 测试结果截图

PC1→R1:

```
PC-1> ping 10.0.0.1
84 bytes from 10.0.0.1 icmp_seq=1 ttl=255 time=9.230 ms
84 bytes from 10.0.0.1 icmp_seq=2 ttl=255 time=2.900 ms
84 bytes from 10.0.0.1 icmp_seq=3 ttl=255 time=10.569 ms
84 bytes from 10.0.0.1 icmp_seq=4 ttl=255 time=9.973 ms
84 bytes from 10.0.0.1 icmp_seq=5 ttl=255 time=8.716 ms
```

PC2→R2:

```
PC-2> ping 10.0.1.1
84 bytes from 10.0.1.1 icmp_seq=1 ttl=255 time=19.492 ms
84 bytes from 10.0.1.1 icmp_seq=2 ttl=255 time=8.973 ms
84 bytes from 10.0.1.1 icmp_seq=3 ttl=255 time=9.804 ms
84 bytes from 10.0.1.1 icmp_seq=4 ttl=255 time=10.585 ms
84 bytes from 10.0.1.1 icmp_seq=5 ttl=255 time=9.364 ms
```

---Part 1：配置 RIP（用于和 OSPF 进行比较）---

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（版本要设置成 2）；

R1 配置命令：

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

R2 配置命令：

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

R3 配置命令：

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

4. 查看 R1、R2、R3 的路由表，跟踪 PC1 到 PC2 的路由；

R1 路由表（标出到 PC2 子网的路由，下一跳是哪个路由器）：

```
     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, 00:00:00, Serial0/0   R2
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, 00:00:06, FastEthernet0/1
                        [120/1] via 10.0.123.242, 00:00:00, Serial0/0
```

R2 路由表（标出到 PC1 子网的路由，下一跳是哪个路由器）：

```
     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, 00:00:16, Serial0/0   R1
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, 00:00:13, FastEthernet1/0
                        [120/1] via 10.0.123.241, 00:00:16, Serial0/0
C       10.0.123.248/29 is directly connected, FastEthernet1/0
```

R3 路由表：

```
     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, 00:00:06, FastEthernet0/1
R       10.0.1.0/24 [120/1] via 10.0.123.249, 00:00:27, FastEthernet1/0
R       10.0.123.240/30 [120/1] via 10.0.123.249, 00:00:27, FastEthernet1/0
                        [120/1] via 10.0.123.245, 00:00:06, FastEthernet0/1
C       10.0.123.244/30 is directly connected, FastEthernet0/1
C       10.0.123.248/29 is directly connected, FastEthernet1/0
```

R1

R2

PC1→PC2 的路由跟踪：（经过的路由器顺序是____R1____、____R2____）

```
PC-1> trace 10.0.1.2
trace to 10.0.1.2, 8 hops max, press Ctrl+C to stop
 1   10.0.0.1   9.177 ms  9.613 ms  9.944 ms
 2   10.0.123.242   9.249 ms  9.693 ms  9.895 ms
 3     *  *  *
 4   *10.0.1.2   9.580 ms (ICMP type:3, code:3, Destination port unreachable)
```

R1

R2

---Part 2：配置单域 OSPF（Area 0）---

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），其中进程 ID 请设置为学号的后 2 位（全 0 者往前取值）。

R1 配置命令：

```
R1(config)#router ospf 46
R1(config-router)#network 10.0.0.0 0.0.255.255 area 0
R1(config-router)#exit
```

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（为 Area 0）。

R2 配置命令：

```
R2(config)#int loopback 0
R2(config-if)#ip addr 10.0.20.1 255.255.255.252
R2(config-if)#exit
R2(config)#router ospf 46
R2(config-router)#network 10.0.0.0 0.0.255.255 area 0
R2(config-router)#exit
```

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：

```
R3(config)#router ospf 46
R3(config-router)#router-id 10.0.30.1
R3(config-router)#network 10.0.0.0 0.0.255.255 area 0
R3(config-router)#exit
```

8. 查看 OSPF 数据库，并标出各路由器的 Router ID。

R1 的 OSPF 数据库：

```
R1#show ip ospf database

            OSPF Router with ID (10.0.123.245) (Process ID 46)

                Router Link States (Area 0)

Link ID         ADV Router      Age         Seq#       Checksum Link count
10.0.20.1       10.0.20.1       213         0x80000002 0x00E5B3 5
10.0.30.1       10.0.30.1       213         0x80000001 0x003F90 2
10.0.123.245    10.0.123.245    212         0x80000003 0x001756 4

                Net Link States (Area 0)

Link ID         ADV Router      Age         Seq#       Checksum
10.0.123.245    10.0.123.245    212         0x80000001 0x00DFC1
10.0.123.249    10.0.20.1       213         0x80000001 0x00FC5D
```

从上图可知，R1 的 Router ID 为 10.0.123.245 （取自接口 Fa0/1 的 IP）；与 R1 连接的有 2 个路由器，其 ID 分别是 10.0.20.1 、 10.0.30.1 ， 有 2 条链路，其 ID 分别是 10.0.123.245 、 10.0.123.249 。

R2 的 OSPF 数据库：

```
R2#show ip ospf database

            OSPF Router with ID (10.0.20.1) (Process ID 46)

                Router Link States (Area 0)

Link ID         ADV Router      Age         Seq#       Checksum Link count
10.0.20.1       10.0.20.1       388         0x80000002 0x00E5B3 5
10.0.30.1       10.0.30.1       389         0x80000001 0x003F90 2
10.0.123.245    10.0.123.245    389         0x80000003 0x001756 4

                Net Link States (Area 0)

Link ID         ADV Router      Age         Seq#       Checksum
10.0.123.245    10.0.123.245    389         0x80000001 0x00DFC1
10.0.123.249    10.0.20.1       388         0x80000001 0x00FC5D
```

从上图可知，R2 的 Router ID 为 10.0.20.1 （取自接口 loopback 0 的 IP）；与 R2 连接的有 2 个路由器，其 ID 分别是 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 OSPF 数据库：

```
R3#show ip ospf database

            OSPF Router with ID (10.0.30.1) (Process ID 46)

                Router Link States (Area 0)

Link ID         ADV Router      Age         Seq#       Checksum Link count
10.0.20.1       10.0.20.1       406         0x80000002 0x00E5B3 5
10.0.30.1       10.0.30.1       405         0x80000001 0x003F90 2
10.0.123.245    10.0.123.245    406         0x80000003 0x001756 4

                Net Link States (Area 0)

Link ID         ADV Router      Age         Seq#       Checksum
10.0.123.245    10.0.123.245    406         0x80000001 0x00DFC1
10.0.123.249    10.0.20.1       407         0x80000001 0x00FC5D
```

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

9. 在路由器 R1 上显示 OSPF 接口数据（命令：show ip ospf interface），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（Designed Router）或者 BDR（Backup Designed

Router）角色。

R1 的 s0/0：（从图可知，s2/0 连接的网络类型为__POINT_TO_POINT__，Cost=__64__，邻居 Router ID=__10.0.20.1__）

```
Serial0/0 is up, line protocol is up
  Internet Address 10.0.123.241/30, Area 0
  Process ID 46, 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 00:00:05
  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)
```

R1 的 f0/1：（f0/1 连接的网络类型为__BOARDCAST__，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__）

```
FastEthernet0/1 is up, line protocol is up
  Internet Address 10.0.123.245/30, Area 0
  Process ID 46, 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 00:00:09
  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 3
  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)
```

R1 的 f0/0：（f0/1 连接的网络类型为__BOARDCAST__，Cost=__10__，DR 的 Router ID 是__10.0.123.245__，接口 IP 是__10.0.0.1__）

```
FastEthernet0/0 is up, line protocol is up
  Internet Address 10.0.0.1/24, Area 0
  Process ID 46, 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 00:00:03
  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)
```

10. 查看 R1、R2、R3 的路由表，与 RIP 比较，OSPF 所选择的路由有何不同，谁的优先级高？跟踪 PC1 到 PC2 的路由。

R1 路由表：（从图可知，对于 PC2 的网络，OSPF 选择的下一跳 IP 地址是__10.0.123.246__，由于 OSPF 的路由管理距离为 110，比 RIP 的管理距离 120 优先级更高，所以把之前 RIP 选择的路由替换了）

```
     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, 00:28:46, FastEthernet0/1
R       10.0.20.0/30 [120/1] via 10.0.123.242, 00:00:18, Serial0/0
O       10.0.20.1/32 [110/12] via 10.0.123.246, 00:28:46, 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, 00:28:48, FastEthernet0/1
```

R2 路由表：（从图可知，对于 PC1 的网络，OSPF 选择的下一跳 IP 地址是 10.0.123.250 ）

```
     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, 00:32:20, 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, 00:32:20, FastEthernet1/0
C       10.0.123.248/29 is directly connected, FastEthernet1/0
```

R3 路由表：

```
O       10.0.0.0/24 [110/20] via 10.0.123.245, 00:33:29, FastEthernet0/1
O       10.0.1.0/24 [110/11] via 10.0.123.249, 00:33:29, FastEthernet1/0
R       10.0.20.0/30 [120/1] via 10.0.123.249, 00:00:21, FastEthernet1/0
O       10.0.20.1/32 [110/2] via 10.0.123.249, 00:33:29, FastEthernet1/0
O       10.0.123.240/30 [110/65] via 10.0.123.249, 00:33:29, FastEthernet1/0
C       10.0.123.244/30 is directly connected, FastEthernet0/1
C       10.0.123.248/29 is directly connected, FastEthernet1/0
```

PC1→PC2 的路由跟踪：（经过的路由器顺序是 R1 、 R3 、 R2 ）

```
PC-1> trace 10.0.1.2
trace to 10.0.1.2, 8 hops max, press Ctrl+C to stop
 1   10.0.0.1   9.213 ms  9.837 ms  9.057 ms
 2   10.0.123.246   20.073 ms  19.620 ms  19.762 ms
 3   10.0.123.249   39.892 ms  40.280 ms  39.709 ms
 4     *  *  *
 5   *10.0.1.2   47.753 ms (ICMP type:3, code:3, Destination port unreachable)
```

11. 断开 R1 和 R3 的接口（在 R1 或 R3 上 shutdown 该接口），再次显示 R1 的路由表，标记到达 PC2 所在子网的下一跳。

R1 的路由表：

```
     10.0.0.0/8 is variably subnetted, 6 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, 00:00:59, Serial0/0
R       10.0.20.0/30 [120/1] via 10.0.123.242, 00:00:02, Serial0/0
O       10.0.20.1/32 [110/65] via 10.0.123.242, 00:00:59, Serial0/0
C       10.0.123.240/30 is directly connected, Serial0/0
O       10.0.123.248/29 [110/65] via 10.0.123.242, 00:00:59, Serial0/0
```

12. 保存 R1 配置后（在 R1 上输入命令：write）重启路由器（右键菜单 reload），查看 R1 的 Router ID 是否发生变化，变成了 10.0.123.241 ，取自 Se0/0 接口的 IP 地址。原因是由于接口 f0/1 断开了，故其上的 IP 地址也暂时不可用，OSPF 于是选择了另一个可用 IP 地址作为 Router ID，而原来的 Router ID 也未消失，看上去是来自另一台不存在的路由器。而 R2 配置了回环接口，OSPF 会优先选择不会断开的回环接口的 IP 地址作为 Router ID，就不会出现上述情况。

R1 的 OSPF 数据库：

```
R1#show ip ospf database

            OSPF Router with ID (10.0.123.241) (Process ID 46)

                Router Link States (Area 0)

Link ID         ADV Router      Age         Seq#       Checksum Link count
10.0.20.1       10.0.20.1       50          0x80000004 0x005942 5
10.0.30.1       10.0.30.1       300         0x80000003 0x00AB33 1
10.0.123.241    10.0.123.241    39          0x80000003 0x004243 3
10.0.123.245    10.0.123.245    331         0x80000005 0x00FD7D 3

                Net Link States (Area 0)

Link ID         ADV Router      Age         Seq#       Checksum
10.0.123.249    10.0.20.1       817         0x80000002 0x00FA5E
```

13. 在 R1 上打开 OSPF 事件调试（命令：debug ip ospf events），然后重新连接 R1 和 R3 的接口（在 R1 或 R3 上 no shutdown 该接口），等与 R3 的邻居关系为 Full 后关闭 debug，最后查看邻居关系。

R1 和 R3 重新建立邻接关系的事件记录：（从图可知，邻接关系建立经历了 5 个状态，分别是 __INIT__、__2WAY__、__EXSTART__、__EXCHANGE__、__FULL__）

```
*Mar  1 00:01:25.371: OSPF: Rcv DBD from 10.0.30.1 on FastEthernet0/1 seq 0x1A90 opt 0x52 flag 0x7 len 32  mtu 1500 state INIT
*Mar  1 00:01:25.371: OSPF: 2 Way Communication to 10.0.30.1 on FastEthernet0/1, state 2WAY
*Mar  1 00:01:25.375: OSPF: Neighbor change Event on interface FastEthernet0/1
*Mar  1 00:01:25.375: OSPF: DR/BDR election on FastEthernet0/1
*Mar  1 00:01:25.375: OSPF: Elect BDR 10.0.30.1
*Mar  1 00:01:25.375: OSPF: Elect DR 10.0.123.245
*Mar  1 00:01:25.375:         DR: 10.0.123.245 (Id)   BDR: 10.0.30.1 (Id)
*Mar  1 00:01:25.375: OSPF: Send DBD to 10.0.30.1 on FastEthernet0/1 seq 0x107A opt 0x52 flag 0x7 len 32
*Mar  1 00:01:25.375: OSPF: First DBD and we are not SLAVE
*Mar  1 00:01:25.379: OSPF: Rcv hello from 10.0.30.1 area 0 from FastEthernet0/1 10.0.123.246
*Mar  1 00:01:25.379: OSPF: Neighbor change Event on interface FastEthernet0/1
*Mar  1 00:01:25.383: OSPF: DR/BDR election on FastEthernet0/1
*Mar  1 00:01:25.383: OSPF: Elect BDR 10.0.30.1
*Mar  1 00:01:25.383: OSPF: Elect DR 10.0.123.245
*Mar  1 00:01:25.383:         DR: 10.0.123.245 (Id)   BDR: 10.0.30.1 (Id)
*Mar  1 00:01:25.383: OSPF: Neighbor change Event on interface FastEthernet0/1
*Mar  1 00:01:25.383: OSPF: DR/BDR election on FastEthernet0/1
*Mar  1 00:01:25.383: OSPF: Elect BDR 10.0.30.1
*Mar  1 00:01:25.383: OSPF: Elect DR 10.0.123.245
*Mar  1 00:01:25.383:         DR: 10.0.123.245 (Id)   BDR: 10.0.30.1 (Id)
*Mar  1 00:01:25.383: OSPF: End of hello processing
*Mar  1 00:01:25.391: OSPF: Rcv DBD from 10.0.30.1 on FastEthernet0/1 seq 0x107A opt 0x52 flag 0x2 len 132  mtu 1500 state EXSTART
*Mar  1 00:01:25.391: OSPF: NBR Negotiation Done. We are the MASTER
*Mar  1 00:01:25.395: OSPF: Send DBD to 10.0.30.1 on FastEthernet0/1 seq 0x107B opt 0x52 flag 0x3 len 132
*Mar  1 00:01:25.403: OSPF: Rcv DBD from 10.0.30.1 on FastEthernet0/1 seq 0x107B opt 0x52 flag 0x0 len 32  mtu 1500 state EXCHANGE
*Mar  1 00:01:25.403: OSPF: Send DBD to 10.0.30.1 on FastEthernet0/1 seq 0x107C opt 0x52 flag 0x1 len 32
*Mar  1 00:01:25.415: OSPF: Rcv DBD from 10.0.30.1 on FastEthernet0/1 seq 0x107C opt 0x52 flag 0x0 len 32  mtu 1500 state EXCHANGE
*Mar  1 00:01:25.415: OSPF: Exchange Done with 10.0.30.1 on FastEthernet0/1
*Mar  1 00:01:25.415: OSPF: Synchronized with 10.0.30.1 on FastEthernet0/1, state FULL
*Mar  1 00:01:25.415: %OSPF-5-ADJCHG: Process 46, Nbr 10.0.30.1 on FastEthernet0/1 from LOADING to FULL, Loading Done
```

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, 6 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 O-bit)
    LLS Options is 0x1 (LR)
    Dead timer due in 00:00:36
    Neighbor is up for 00:04:32
    Index 2/2, 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
 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, 12 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 O-bit)
    LLS Options is 0x1 (LR)
    Dead timer due in 00:00:34
    Neighbor is up for 00:05:37
    Index 1/1, 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
```

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（由于 R2、R3、R4、R6 在同一个广播网络中，四台路由器并不会都成为邻接关系，而是选出 DR、BDR，然后各路由器与 DR、BDR 进行路由信息交换）。

R4 配置命令：

```
R4(config)#int f0/0
R4(config-if)#ip addr 10.0.123.251 255.255.255.248
R4(config-if)#no shut
R4(config-if)#exit
R4(config)#int loopback 0
R4(config-if)#ip addr 10.0.40.1 255.255.255.252
R4(config-if)#exit
R4(config)#router ospf 46
R4(config-router)#network 10.0.0.0 0.0.255.255 area 0
R4(config-router)#exit
```

R6 配置命令：

```
R6(config)#int f0/0
R6(config-if)#ip addr 10.0.123.252 255.255.255.248
R6(config-if)#no shut
R6(config-if)#exit
```

R6(config)#int loopback 0

R6(config-if)#ip addr 10.0.60.1 255.255.255.252

R6(config-if)#exit

R6(config)#router ospf 46

R6(config-router)#network 10.0.0.0 0.0.255.255 area 0

R6(config-router)#exit

R4 上查看邻居关系（与 R6 是邻居，但不建立邻接关系，重启后可能会变化）：

```
R4#show ip ospf neighbor

Neighbor ID     Pri   State           Dead Time   Address         Interface
10.0.20.1         1   FULL/DR         00:00:30    10.0.123.249    FastEthernet0/0
10.0.30.1         1   FULL/BDR        00:00:38    10.0.123.250    FastEthernet0/0
10.0.60.1         1   2WAY/DROTHER    00:00:33    10.0.123.252    FastEthernet0/0
```

R6 上查看邻居关系（与 R4 是邻居，但不建立邻接关系，重启后可能会变化）：

```
R6#show ip ospf neighbor

Neighbor ID     Pri   State           Dead Time   Address         Interface
10.0.20.1         1   FULL/DR         00:00:37    10.0.123.249    FastEthernet0/0
10.0.30.1         1   FULL/BDR        00:00:35    10.0.123.250    FastEthernet0/0
10.0.40.1         1   2WAY/DROTHER    00:00:30    10.0.123.251    FastEthernet0/0
```

---Part 3：配置多域 OSPF---

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（替换成文本形式）：

```
R4(config)#int f0/1
R4(config-if)#ip addr 10.1.0.1 255.255.255.0
R4(config-if)#no shut
R4(config-if)#exit

R4(config)#router ospf 46
R4(config-router)#network 10.1.0.0 0.0.255.255 area 1
R4(config-router)#exit
```

R5 配置命令：

```
R5(config)#int f0/1
R5(config-if)#ip addr 10.1.0.2 255.255.255.0
R5(config-if)#no shut
R5(config-if)#exit

R5(config)#int loopback 0
```

```
R5(config-if)#ip addr 10.1.50.1 255.255.255.252
R5(config-if)#exit

R5(config)#int f0/0
R5(config-if)#ip addr 10.1.1.1 255.255.255.0
R5(config-if)#no shut
R5(config-if)#exit

R5(config)#router ospf 46
R5(config-router)#network 10.1.0.0 0.0.255.255 area 1
R5(config-router)#exit
```

PC3 配置命令：

```
PC-3> ip 10.1.1.2 255.255.255.0 10.1.1.1
```

R2 的路由表：目标为 Area 1 中的子网的下一跳 IP 地址均为 10.0.123.251 ，从 Fa1/0 接口发出。

```
     10.0.0.0/8 is variably subnetted, 11 subnets, 4 masks
O IA    10.1.1.0/24 [110/21] via 10.0.123.251, 00:06:06, FastEthernet1/0
O       10.0.0.0/24 [110/21] via 10.0.123.250, 00:06:06, FastEthernet1/0
O IA    10.1.0.0/24 [110/11] via 10.0.123.251, 00:06:06, 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 10.0.123.251, 00:06:06, FastEthernet1/0
O       10.0.60.1/32 [110/2] via 10.0.123.252, 00:06:07, FastEthernet1/0
O IA    10.1.50.1/32 [110/12] via 10.0.123.251, 00:03:12, 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, 00:06:07, FastEthernet1/0
C       10.0.123.248/29 is directly connected, FastEthernet1/0
```

R5 的路由表：目标为 Area 0 中的子网的下一跳 IP 地址均为 10.1.0.1 ，从 Fa0/1 接口发出。

```
     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, 00:03:59, 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, 00:03:59, FastEthernet0/1
O IA    10.0.20.1/32 [110/21] via 10.1.0.1, 00:03:59, FastEthernet0/1
O IA    10.0.40.1/32 [110/11] via 10.1.0.1, 00:03:59, FastEthernet0/1
O IA    10.0.60.1/32 [110/21] via 10.1.0.1, 00:04:00, FastEthernet0/1
C       10.0.50.0/30 is directly connected, Loopback0
O IA    10.0.123.240/30 [110/84] via 10.1.0.1, 00:04:00, FastEthernet0/1
O IA    10.0.123.244/30 [110/30] via 10.1.0.1, 00:04:00, FastEthernet0/1
O IA    10.0.123.248/29 [110/20] via 10.1.0.1, 00:04:00, FastEthernet0/1
```

PC3→PC1 的连通性：

```
PC-3> 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=56.911 ms
84 bytes from 10.0.0.2 icmp_seq=3 ttl=60 time=41.632 ms
84 bytes from 10.0.0.2 icmp_seq=4 ttl=60 time=47.777 ms
84 bytes from 10.0.0.2 icmp_seq=5 ttl=60 time=48.701 ms
```

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。

```
R2#show ip ospf database

            OSPF Router with ID (10.0.20.1) (Process ID 46)

                Router Link States (Area 0)

Link ID         ADV Router      Age         Seq#       Checksum Link count
10.0.20.1       10.0.20.1       1079        0x8000000F 0x00E1A9 5
10.0.30.1       10.0.30.1       1458        0x80000008 0x003B8C 2
10.0.40.1       10.0.40.1       1159        0x80000008 0x006A0B 2
10.0.60.1       10.0.60.1       1341        0x80000003 0x00D667 2
10.0.123.245    10.0.123.245    1335        0x8000000C 0x00055F 4

                Net Link States (Area 0)

Link ID         ADV Router      Age         Seq#       Checksum
10.0.123.245    10.0.123.245    1597        0x80000003 0x00DBC3
10.0.123.250    10.0.30.1       1086        0x80000009 0x009D27

                Summary Net Link States (Area 0)

Link ID         ADV Router      Age         Seq#       Checksum
10.1.0.0        10.0.40.1       1158        0x80000003 0x00E111
10.1.1.0        10.0.40.1       1114        0x80000001 0x003FAA
10.1.50.1       10.0.40.1       61          0x80000001 0x00BD03
```

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。

```
R5#show ip ospf database

            OSPF Router with ID (10.0.50.1) (Process ID 46)

                Router Link States (Area 1)

Link ID         ADV Router      Age         Seq#       Checksum Link count
10.0.40.1       10.0.40.1       1064        0x80000002 0x00BAED 1
10.0.50.1       10.0.50.1       11          0x80000004 0x00021B 3

                Net Link States (Area 1)

Link ID         ADV Router      Age         Seq#       Checksum
10.1.0.2        10.0.50.1       1063        0x80000001 0x00D7A7

                Summary Net Link States (Area 1)

Link ID         ADV Router      Age         Seq#       Checksum
10.0.0.0        10.0.40.1       1098        0x80000001 0x00BA27
10.0.1.0        10.0.40.1       1021        0x80000004 0x0045A2
10.0.20.1       10.0.40.1       1031        0x80000003 0x0011CC
10.0.40.1       10.0.40.1       1108        0x80000001 0x00D302
10.0.60.1       10.0.40.1       1098        0x80000001 0x005B5C
10.0.123.240    10.0.40.1       1031        0x80000003 0x00A6A3
10.0.123.244    10.0.40.1       1098        0x80000001 0x00641A
10.0.123.248    10.0.40.1       1111        0x80000001 0x00BFC8
```

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、10.020.1、10.0.40.1、10.0.60.1、10.0.123.240、10.0.123.244、10.0.123.248。

```
R4#show ip ospf database

            OSPF Router with ID (10.0.40.1) (Process ID 46)

                Router Link States (Area 0)

Link ID         ADV Router      Age         Seq#       Checksum Link count
10.0.20.1       10.0.20.1       1247        0x8000000F 0x00E1A9 5
10.0.30.1       10.0.30.1       1622        0x80000008 0x003B8C 2
10.0.40.1       10.0.40.1       1321        0x80000008 0x006A0B 2
10.0.60.1       10.0.60.1       1505        0x80000003 0x00D667 2
10.0.123.245    10.0.123.245    1502        0x8000000C 0x00055F 4

                Net Link States (Area 0)

Link ID         ADV Router      Age         Seq#       Checksum
10.0.123.245    10.0.123.245    1763        0x80000003 0x00DBC3
10.0.123.250    10.0.30.1       1250        0x80000009 0x009D27

                Summary Net Link States (Area 0)

Link ID         ADV Router      Age         Seq#       Checksum
10.1.0.0        10.0.40.1       1321        0x80000003 0x00E111
10.1.1.0        10.0.40.1       1277        0x80000001 0x003FAA
10.1.50.1       10.0.40.1       225         0x80000001 0x00BD03

                Router Link States (Area 1)

Link ID         ADV Router      Age         Seq#       Checksum Link count
10.0.40.1       10.0.40.1       1283        0x80000002 0x00BAED 1
10.0.50.1       10.0.50.1       234         0x80000004 0x00021B 3

                Net Link States (Area 1)

Link ID         ADV Router      Age         Seq#       Checksum
10.1.0.2        10.0.50.1       1286        0x80000001 0x00D7A7

                Summary Net Link States (Area 1)

Link ID         ADV Router      Age         Seq#       Checksum
10.0.0.0        10.0.40.1       1321        0x80000001 0x00BA27
10.0.1.0        10.0.40.1       1246        0x80000004 0x0045A2
10.0.20.1       10.0.40.1       1256        0x80000003 0x0011CC
10.0.40.1       10.0.40.1       1333        0x80000001 0x00D302
10.0.60.1       10.0.40.1       1323        0x80000001 0x005B5C
10.0.123.240    10.0.40.1       1257        0x80000003 0x00A6A3
10.0.123.244    10.0.40.1       1324        0x80000001 0x00641A
10.0.123.248    10.0.40.1       1335        0x80000001 0x00BFC8
```

17. 分别在 R1、R5 上查看区域边界路由器（ABR）信息（命令：show ip ospf border-routers)

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。

```
R1#show ip ospf border-routers

OSPF Process 46 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 22
```

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。

```
R5#show ip ospf border-routers

OSPF Process 46 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 6
```

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：

```
R6(config)#interface f0/1
R6(config-if)# ip addr 10.2.1.2 255.255.255.0
R6(config-if)# no shut
R6(config)# router ospf 46
R6(config-router)# network 10.2.0.0 0.0.255.255 area 2
```

R8 配置命令：

```
R8(config)#interface f0/1
R8(config-if)# ip addr 10.2.1.1 255.255.255.0
R8(config-if)# no shut
R8(config)#interface f0/0
R8(config-if)# ip addr 10.2.0.2 255.255.255.0
R8(config-if)# no shut
R8(config)#interface f1/0
R8(config-if)# ip addr 10.2.1.1 255.255.255.0
R8(config-if)# no shut
R8(config)#interface loopback 0
R8(config-if)# ip addr 10.2.80.1 255.255.255.252
R8(config)# router ospf 46
R8(config-router)# network 10.2.0.0 0.0.255.255 area 2
```

R8 的路由表：如图所示，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 10.1.1.0/24 、10.1.0.0/24 、10.1.50.1/32 。

```
     10.0.0.0/8 is variably subnetted, 15 subnets, 4 masks
C       10.2.0.0/24 is directly connected, FastEthernet0/0
C       10.2.1.0/24 is directly connected, FastEthernet0/1
C       10.2.2.0/24 is directly connected, FastEthernet1/0
O IA    10.1.1.0/24 [110/40] via 10.2.1.2, 00:00:18, FastEthernet0/1
O IA    10.0.0.0/24 [110/40] via 10.2.1.2, 00:00:18, FastEthernet0/1
O IA    10.1.0.0/24 [110/30] via 10.2.1.2, 00:00:18, FastEthernet0/1
O IA    10.0.1.0/24 [110/30] via 10.2.1.2, 00:00:18, FastEthernet0/1
O IA    10.0.20.1/32 [110/21] via 10.2.1.2, 00:00:19, FastEthernet0/1
O IA    10.0.40.1/32 [110/21] via 10.2.1.2, 00:00:19, FastEthernet0/1
O IA    10.0.60.1/32 [110/11] via 10.2.1.2, 00:00:19, FastEthernet0/1
O IA    10.1.50.1/32 [110/31] via 10.2.1.2, 00:00:19, FastEthernet0/1
C       10.2.80.0/30 is directly connected, Loopback0
O IA    10.0.123.240/30 [110/84] via 10.2.1.2, 00:00:20, FastEthernet0/1
O IA    10.0.123.244/30 [110/30] via 10.2.1.2, 00:00:21, FastEthernet0/1
O IA    10.0.123.248/29 [110/20] via 10.2.1.2, 00:00:21, FastEthernet0/1
```

PC4→PC1 的连通性：

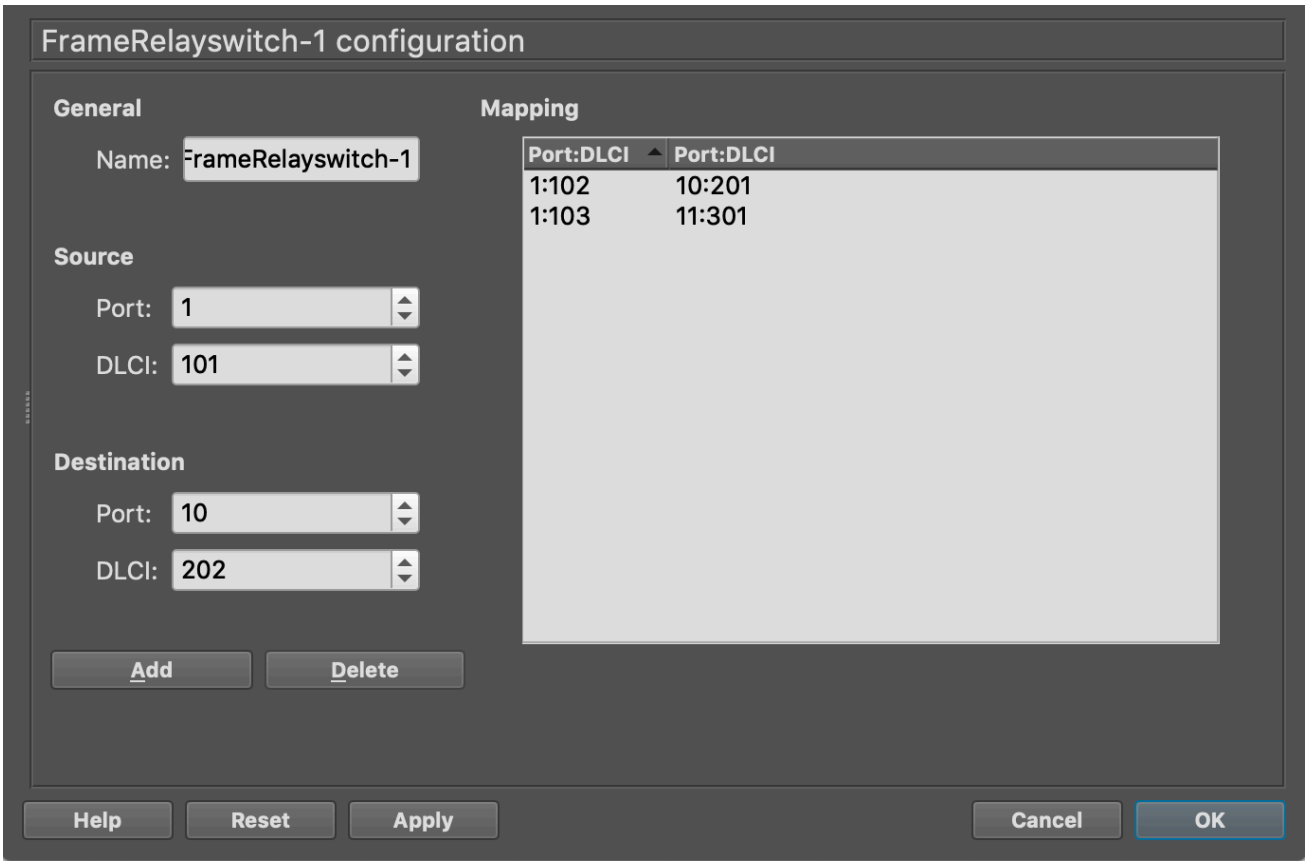
```
PC-4> ping 10.0.0.2
10.0.0.2 icmp_seq=1 timeout
10.0.0.2 icmp_seq=2 timeout
84 bytes from 10.0.0.2 icmp_seq=3 ttl=60 time=66.669 ms
84 bytes from 10.0.0.2 icmp_seq=4 ttl=60 time=47.632 ms
84 bytes from 10.0.0.2 icmp_seq=5 ttl=60 time=48.767 ms
```

PC4→PC3 的连通性：

```
PC-4> ping 10.1.1.2
10.1.1.2 icmp_seq=1 timeout
84 bytes from 10.1.1.2 icmp_seq=2 ttl=60 time=69.331 ms
84 bytes from 10.1.1.2 icmp_seq=3 ttl=60 time=59.671 ms
84 bytes from 10.1.1.2 icmp_seq=4 ttl=60 time=58.608 ms
84 bytes from 10.1.1.2 icmp_seq=5 ttl=60 time=58.181 ms
```

19. 如果之前未配置 Frame Relay 数据链路，请在此时进行配置（参考 GNS3 指南）。

FR 交换机的虚链路配置表截图：



20. 给 R5 的 s0/0 接口配置封装协议为 Frame Relay（命令：encapsulation frame-relay，由于 GNS3 自带的 FR 交换机只支持 ANSI 模式，而路由器默认的是 Cisco，所以需再加一句 frame-relay lmi-type ANSI)并激活，然后创建 2 个子接口，配置其 IP 地址、接口 DLCI（命令：frame-relay interface-dlci <dlci>, dlci 值等于 Frame Relay 交换机上定义的数据链路相关 DLCI 值），最后配置 R5 的 s2/0 接口属于 Area 1。

R5 配置命令：

```
R5(config)#int s0/0
R5(config-if)#encapsu frame-relay
R5(config-if)#frame-relay lmi-type ANSI
R5(config-if)#no shut
R5(config-if)#exit

R5(config)#int s0/0.1 multipoint
R5(config-subif)#ip address 10.1.2.1 255.255.255.0
```

```
R5(config-subif)#frame-relay map ip 10.1.2.3 102 broadcast
R5(config-subif)#frame-relay interface-dlci 102
R5(config-fr-dlci)#exit
R5(config-subif)#exit

R5(config)#int s0/0.2 multipoint
R5(config-subif)#ip address 10.1.2.2 255.255.255.0
R5(config-subif)#frame-relay map ip 10.1.2.4 103 broadcast
R5(config-subif)#frame-relay interface-dlci 103
R5(config-fr-dlci)#exit
R5(config-subif)#exit
```

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，s2/0 接口属于 Area 1，配置 s2/0 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：

```
R7(config)#interface f0/0
R7(config-if)# ip addr 10.2.0.2 255.255.255.0
R7(config-if)# no shut
R7(config)#interface s0/0
R7(config-if)# ip addr 10.1.2.3 255.255.255.0          (IP 地址)
R7(config-if)# encapsu frame-relay                     (封装协议)
R7(config-if)# frame-relay lmi-type ANSI               (LMI)
R7(config-if)# frame-relay interface-dlci 201          (DLCI)
R7(config-if)# frame-relay map ip 10.1.2.1 201 broadcast
R7(config-if)# no shut                                 (激活)
R7(config)#interface loopback 0
R7(config-if)# ip addr 10.2.70.1 255.255.255.252
R7(config)# router ospf 46
R7(config-router)# network 10.2.0.0 0.0.255.255 area 2
R7(config-router)# network 10.1.0.0 0.0.255.255 area 1
```

在 R7 上查看 Frame Relay 映射（命令：show frame-relay map）：

```
R7#show frame-relay map
Serial0/0 (up): ip 10.1.2.1 dlci 201(0xC9,0x3090), static,
              broadcast,
              CISCO, status defined, active
```

在 R5 上查看 Frame Relay 映射（命令：show frame-relay map）：

```
R5#show frame-relay map
Serial0/0.1 (up): ip 10.1.2.3 dlci 102(0x66,0x1860), static,
              broadcast,
              CISCO, status defined, active
```

在 R7 上测试到 R5 的连通性（由于 R5-R7 采用的是点对点 Frame Relay 连接，只有 R5 的 1 个子接口地址可以通）：

```
R7#ping 10.1.2.1

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.1.2.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/6/20 ms
```

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，s2/0 接口属于 Area 1，配置 s2/0 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：

```
R9(config)#interface f0/1
R9(config-if)# ip addr 10.3.0.1 255.255.255.0
R9(config-if)# no shut
R9(config)#interface s0/0
R9(config-if)# ip addr 10.1.2.4 255.255.255.0          (IP 地址)
R9(config-if)# encapsu frame-relay                      (封装协议)
R9(config-if)# frame-relay lmi-type ANSI                (LMI)
R9(config-if)# frame-relay interface-dlci 301           (DLCI)
R9(config-if)# frame-relay map ip 10.1.2.2 301 broadcast
R9(config-if)# no shut                                  (激活)
R9(config)#interface loopback 0
R9(config-if)# ip addr 10.3.90.1 255.255.255.252
R9(config)# router ospf 46
R9(config-router)# network 10.1.0.0 0.0.255.255 area 1
R9(config-router)# network 10.3.0.0 0.0.255.255 area 3
```

在 R9 上查看 Frame Relay 映射（命令：show frame-relay map）：

```
R9#show frame-relay map
Serial0/0 (up): ip 10.1.2.2 dlci 301(0x12D,0x48D0), static,
              broadcast,
              CISCO, status defined, active
```

在 R9 上测试到 R5 的连通性（由于 R5-R9 采用的是点对点 Frame Relay 连接，只有 R5 的 1 个子接口地址可以通。如果在 R5 上测试，需要加上参数 source s2/0 指定接口）：

```
R9#ping 10.1.2.2

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.1.2.2, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/3/4 ms
```

在 R9 上测试到 R7 的连通性（R5、R7、R9 通过帧中继交换机连接的形式称为非广播式多路访问，虽然路由器在同一个 IP 子网，但由于数据链路不是广播式的，所以在没有建立点对点数据链路的情况下，是不能通信的）：

```
R9#ping 10.1.2.3

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.1.2.3, timeout is 2 seconds:
.....
Success rate is 0 percent (0/5)
```

23. 分别在 R5、R7、R9 上查看 OSPF 邻居关系（此时 OSPF 认为当前链路属于广播式，需要先竞选出 DR，而实际网络为非广播式的，因此三者之间的邻居关系暂时不能建立）

在 R5 上查看邻居关系:

```
R5#show ip ospf neighbor

Neighbor ID     Pri   State           Dead Time   Address         Interface
10.0.40.1         1   FULL/BDR        00:00:37    10.1.0.1        FastEthernet0/1
```

在 R7 上查看邻居关系:

```
R7#show ip ospf neighbor

Neighbor ID     Pri   State           Dead Time   Address         Interface
10.2.80.1         1   FULL/DR         00:00:39    10.2.3.2        FastEthernet0/0
```

在 R9 上查看邻居关系:

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

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（命令：ip ospf network point-to-multipoint），然后再次查看邻居关系：

R5 配置命令：

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

R7 配置命令：

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

R9 配置命令：

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

在 R5 上查看邻居关系:

```
R5#show ip ospf neighbor

Neighbor ID     Pri   State           Dead Time   Address         Interface
10.0.40.1         1   FULL/DR         00:00:34    10.1.0.1        FastEthernet0/1
10.3.90.1         0   FULL/  -        00:01:52    10.1.2.4        Serial0/0.2
10.2.70.1         0   FULL/  -        00:01:56    10.1.2.3        Serial0/0.1
```

在 R7 上查看邻居关系:

```
R7#show ip ospf neighbor

Neighbor ID     Pri   State           Dead Time   Address         Interface
10.1.50.1         0   FULL/  -        00:01:38    10.1.2.1        Serial0/0
10.2.80.1         1   FULL/DR         00:00:31    10.2.3.2        FastEthernet0/0
```

在 R9 上查看邻居关系:

```
R9#show ip ospf neighbor

Neighbor ID     Pri   State           Dead Time   Address         Interface
10.1.50.1         0   FULL/  -        00:01:49    10.1.2.2        Serial0/0
```

25. 分别在 R5、R8、R7 上查看 OSPF 数据库（命令：show ip ospf database），观察 Summary Net Link 部

分，你发现了什么现象？

R5 的 OSPF 数据库：观察得知，Area 1 所有的的聚合路由都是由区域边界路由器(ABR)__R4__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。

```
R5#show ip ospf database

            OSPF Router with ID (10.1.50.1) (Process ID 46)

                Router Link States (Area 1)

Link ID         ADV Router      Age         Seq#       Checksum Link count
10.0.40.1       10.0.40.1       670         0x80000009 0x00A2FF 1
10.0.50.1       10.0.50.1       1250        0x8000000F 0x0085D1 5
10.1.50.1       10.1.50.1       104         0x80000007 0x007BEA 7
10.2.70.1       10.2.70.1       126         0x8000000A 0x008EE4 3
10.3.90.1       10.3.90.1       105         0x80000005 0x00713E 2

                Net Link States (Area 1)

Link ID         ADV Router      Age         Seq#       Checksum
10.1.0.1        10.0.40.1       670         0x80000001 0x005C2D

                Summary Net Link States (Area 1)

Link ID         ADV Router      Age         Seq#       Checksum
10.0.0.0        10.0.40.1       1003        0x80000007 0x00AE2D
10.0.1.0        10.0.40.1       1003        0x8000000A 0x0039A8
10.0.20.1       10.0.40.1       1003        0x80000009 0x0005D2
10.0.40.1       10.0.40.1       1003        0x80000007 0x00C708
10.0.60.1       10.0.40.1       1005        0x80000007 0x004F62
10.0.123.240    10.0.40.1       1006        0x80000009 0x009AA9
10.0.123.244    10.0.40.1       1006        0x80000007 0x005820
10.0.123.248    10.0.40.1       1006        0x80000007 0x00B3CE
10.2.1.0        10.0.40.1       1263        0x80000006 0x0029BA
10.2.2.0        10.0.40.1       1007        0x80000006 0x0028B9
10.2.3.0        10.0.40.1       248         0x80000004 0x007B5E
10.2.80.1       10.0.40.1       1008        0x80000006 0x00C0D1
```

R8 的 OSPF 数据库：观察得知，Area 2 所有的的聚合路由都是由区域边界路由器(ABR)__R6__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，。

```
R8#show ip ospf database

            OSPF Router with ID (10.2.80.1) (Process ID 46)

                Router Link States (Area 1)

Link ID         ADV Router      Age         Seq#       Checksum Link count
10.2.80.1       10.2.80.1       370         0x80000004 0x00DCA8 0

                Router Link States (Area 2)

Link ID         ADV Router      Age         Seq#       Checksum Link count
10.0.60.1       10.0.60.1       1274        0x80000007 0x007FF6 1
10.2.70.1       10.2.70.1       1915        0x80000006 0x00BF9D 1
10.2.80.1       10.2.80.1       1871        0x80000008 0x00176B 4

                Net Link States (Area 2)

Link ID         ADV Router      Age         Seq#       Checksum
10.2.1.2        10.0.60.1       1274        0x80000006 0x00EC4D
10.2.3.2        10.2.80.1       1871        0x80000003 0x008296

                Summary Net Link States (Area 2)

Link ID         ADV Router      Age         Seq#       Checksum
10.0.0.0        10.0.60.1       1524        0x80000006 0x0024A4
10.0.1.0        10.0.60.1       1526        0x80000006 0x00B41D
10.0.20.1       10.0.60.1       1526        0x80000006 0x007E48
10.0.40.1       10.0.60.1       1527        0x80000006 0x00A111
10.0.60.1       10.0.60.1       1527        0x80000006 0x006048
10.0.123.240    10.0.60.1       1527        0x80000006 0x00141F
10.0.123.244    10.0.60.1       1527        0x80000006 0x00CD97
10.0.123.248    10.0.60.1       1527        0x80000006 0x002946
10.1.0.0        10.0.60.1       1527        0x80000006 0x00B31E
10.1.1.0        10.0.60.1       700         0x80000008 0x0009BB
10.1.2.1        10.0.60.1       318         0x80000001 0x009D36
10.1.2.2        10.0.60.1       175         0x80000001 0x00933F
10.1.2.3        10.0.60.1       165         0x80000001 0x000C85
10.1.2.4        10.0.60.1       135         0x80000001 0x00028E
10.1.50.1       10.0.60.1       1528        0x80000006 0x008B12
10.1.70.1       10.0.60.1       165         0x80000001 0x003B13
```

R7 的 OSPF 数据库：观察得知，Area 1 所有的的聚合路由都是由区域边界路由器(ABR)___R4___宣告的，

Area 2 所有的的聚合路由都是由区域边界路由器(ABR)___R6___宣告的。

```
R7#show ip ospf database

            OSPF Router with ID (10.2.70.1) (Process ID 46)

                Router Link States (Area 1)

Link ID         ADV Router      Age         Seq#       Checksum Link count
10.0.40.1       10.0.40.1       721         0x80000009 0x00A2FF 1
10.0.50.1       10.0.50.1       1301        0x8000000F 0x0085D1 5
10.1.50.1       10.1.50.1       155         0x80000007 0x007BEA 7
10.2.70.1       10.2.70.1       176         0x8000000A 0x008EE4 3
10.3.90.1       10.3.90.1       156         0x80000005 0x00713E 2

                Net Link States (Area 1)

Link ID         ADV Router      Age         Seq#       Checksum
10.1.0.1        10.0.40.1       721         0x80000001 0x005C2D

                Summary Net Link States (Area 1)

Link ID         ADV Router      Age         Seq#       Checksum
10.0.0.0        10.0.40.1       1054        0x80000007 0x00AE2D
10.0.1.0        10.0.40.1       1054        0x8000000A 0x0039A8
10.0.20.1       10.0.40.1       1054        0x80000009 0x0005D2
10.0.40.1       10.0.40.1       1054        0x80000007 0x00C708
10.0.60.1       10.0.40.1       1055        0x80000007 0x004F62
10.0.123.240    10.0.40.1       1056        0x80000009 0x009AA9
10.0.123.244    10.0.40.1       1056        0x80000007 0x005820
10.0.123.248    10.0.40.1       1056        0x80000007 0x00B3CE
10.2.1.0        10.0.40.1       1313        0x80000006 0x0029BA
10.2.2.0        10.0.40.1       1056        0x80000006 0x0028B9
10.2.3.0        10.0.40.1       298         0x80000004 0x007B5E
10.2.80.1       10.0.40.1       1056        0x80000006 0x00C0D1

                Router Link States (Area 2)

Link ID         ADV Router      Age         Seq#       Checksum Link count
10.0.60.1       10.0.60.1       1286        0x80000007 0x007FF6 1
10.2.70.1       10.2.70.1       1926        0x80000006 0x00BF9D 1
10.2.80.1       10.2.80.1       1884        0x80000008 0x00176B 4

                Net Link States (Area 2)

Link ID         ADV Router      Age         Seq#       Checksum
10.2.1.2        10.0.60.1       1287        0x80000006 0x00EC4D
10.2.3.2        10.2.80.1       1886        0x80000003 0x008296

                Summary Net Link States (Area 2)

Link ID         ADV Router      Age         Seq#       Checksum
10.0.0.0        10.0.60.1       1540        0x80000006 0x0024A4
10.0.1.0        10.0.60.1       1541        0x80000006 0x00B41D
10.0.20.1       10.0.60.1       1541        0x80000006 0x007E48
10.0.40.1       10.0.60.1       1541        0x80000006 0x00A111
10.0.60.1       10.0.60.1       1541        0x80000006 0x006048
10.0.123.240    10.0.60.1       1541        0x80000006 0x00141F
10.0.123.244    10.0.60.1       1541        0x80000006 0x00CD97
10.0.123.248    10.0.60.1       1542        0x80000006 0x002946
10.1.0.0        10.0.60.1       1542        0x80000006 0x00B31E
10.1.1.0        10.0.60.1       715         0x80000008 0x0009BB
10.1.2.1        10.0.60.1       333         0x80000001 0x009D36
10.1.2.2        10.0.60.1       189         0x80000001 0x00933F
10.1.2.3        10.0.60.1       180         0x80000001 0x000C85
10.1.2.4        10.0.60.1       150         0x80000001 0x00028E
10.1.50.1       10.0.60.1       1543        0x80000006 0x008B12
10.1.70.1       10.0.60.1       180         0x80000001 0x003B13
```

26. 在 R8 上查看去往 PC3 所在网络的路由信息（命令：show ip route <ip network>）

R8 的路由信息：观察得知，前往子网 10.1.1.0/24 的下一跳 IP 地址是 10.2.1.2，是路由器 R6。

```
R8#show ip route 10.1.1.0
Routing entry for 10.1.1.0/24
  Known via "ospf 46", distance 110, metric 40, type inter area
  Last update from 10.2.1.2 on FastEthernet0/1, 00:13:40 ago
  Routing Descriptor Blocks:
  * 10.2.1.2, from 10.0.60.1, 00:13:40 ago, via FastEthernet0/1
      Route metric is 40, traffic share count is 1
```

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

R8 的路由信息：观察得知，前往子网 10.0.0.0/16 的路由已经不存在。

```
     10.0.0.0/8 is variably subnetted, 5 subnets, 3 masks
C       10.2.1.0/24 is directly connected, FastEthernet0/1
C       10.2.2.0/24 is directly connected, FastEthernet1/0
C       10.2.3.0/24 is directly connected, FastEthernet0/0
O IA    10.0.60.1/32 [110/11] via 10.2.1.2, 01:48:17, FastEthernet0/1
C       10.2.80.0/30 is directly connected, Loopback0
```

看看 R7 有没有 PC3 的路由信息：观察得知，前往子网 10.1.0.0/16 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
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, 20 subnets, 4 masks
O       10.1.2.1/32 [110/64] via 10.1.2.1, 00:17:50, Serial0/0
O       10.2.1.0/24 [110/20] via 10.2.3.2, 00:57:36, FastEthernet0/0
C       10.1.2.0/24 is directly connected, Serial0/0
O       10.2.2.0/24 [110/11] via 10.2.3.2, 00:57:36, FastEthernet0/0
O       10.1.1.0/24 [110/74] via 10.1.2.1, 00:17:50, Serial0/0
O IA    10.0.0.0/24 [110/104] via 10.1.2.1, 00:01:57, Serial0/0
C       10.2.3.0/24 is directly connected, FastEthernet0/0
O       10.1.2.2/32 [110/64] via 10.1.2.1, 00:17:52, Serial0/0
O       10.1.0.0/24 [110/74] via 10.1.2.1, 00:17:52, Serial0/0
O IA    10.0.1.0/24 [110/94] via 10.1.2.1, 00:01:58, Serial0/0
O       10.1.2.4/32 [110/128] via 10.1.2.1, 00:17:52, Serial0/0
O IA    10.0.20.1/32 [110/85] via 10.1.2.1, 00:01:58, Serial0/0
O IA    10.0.40.1/32 [110/75] via 10.1.2.1, 00:01:59, Serial0/0
O IA    10.0.60.1/32 [110/21] via 10.2.3.2, 00:01:22, FastEthernet0/0
O       10.1.50.1/32 [110/65] via 10.1.2.1, 00:17:53, Serial0/0
C       10.1.70.0/30 is directly connected, Loopback0
O       10.2.80.1/32 [110/11] via 10.2.3.2, 00:57:39, FastEthernet0/0
O IA    10.0.123.240/30 [110/148] via 10.1.2.1, 00:02:00, Serial0/0
O IA    10.0.123.244/30 [110/94] via 10.1.2.1, 00:02:00, Serial0/0
O IA    10.0.123.248/29 [110/84] via 10.1.2.1, 00:02:01, Serial0/0
```

重新打开 R6 的 f0/0 接口，稍候再次查看 R8 的路由信息是否恢复。

```
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, 5 subnets, 3 masks
C       10.2.1.0/24 is directly connected, FastEthernet0/1
C       10.2.2.0/24 is directly connected, FastEthernet1/0
C       10.2.3.0/24 is directly connected, FastEthernet0/0
O IA    10.0.60.1/32 [110/11] via 10.2.1.2, 01:48:17, FastEthernet0/1
C       10.2.80.0/30 is directly connected, Loopback0
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, 20 subnets, 4 masks
O IA    10.1.2.1/32 [110/30] via 10.2.1.2, 00:00:29, FastEthernet0/1
C       10.2.1.0/24 is directly connected, FastEthernet0/1
C       10.2.2.0/24 is directly connected, FastEthernet1/0
O IA    10.1.2.3/32 [110/94] via 10.2.1.2, 00:00:29, FastEthernet0/1
O IA    10.1.1.0/24 [110/40] via 10.2.1.2, 00:00:29, FastEthernet0/1
O IA    10.0.0.0/24 [110/40] via 10.2.1.2, 00:00:29, FastEthernet0/1
C       10.2.3.0/24 is directly connected, FastEthernet0/0
O IA    10.1.2.2/32 [110/30] via 10.2.1.2, 00:00:30, FastEthernet0/1
O IA    10.1.0.0/24 [110/30] via 10.2.1.2, 00:00:30, FastEthernet0/1
O IA    10.0.1.0/24 [110/30] via 10.2.1.2, 00:00:30, FastEthernet0/1
O IA    10.1.2.4/32 [110/94] via 10.2.1.2, 00:00:30, FastEthernet0/1
O IA    10.0.20.1/32 [110/21] via 10.2.1.2, 00:00:30, FastEthernet0/1
O IA    10.0.40.1/32 [110/21] via 10.2.1.2, 00:00:31, FastEthernet0/1
O IA    10.0.60.1/32 [110/11] via 10.2.1.2, 01:50:39, FastEthernet0/1
O IA    10.1.50.1/32 [110/31] via 10.2.1.2, 00:00:32, FastEthernet0/1
O IA    10.1.70.1/32 [110/95] via 10.2.1.2, 00:00:32, FastEthernet0/1
C       10.2.80.0/30 is directly connected, Loopback0
O IA    10.0.123.240/30 [110/84] via 10.2.1.2, 00:00:32, FastEthernet0/1
O IA    10.0.123.244/30 [110/30] via 10.2.1.2, 00:00:33, FastEthernet0/1
O IA    10.0.123.248/29 [110/20] via 10.2.1.2, 00:00:33, FastEthernet0/1
```

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：

```
R10(config)#interface f0/1
R10(config-if)# ip addr 10.3.0.2 255.255.255.0
R10(config-if)# no shut
R10(config)#interface f0/0
R10(config-if)# ip addr 10.3.1.1 255.255.255.0
R10(config-if)# no shu
R10(config)#interface loopback 0
R10(config-if)# ip addr 10.3.100.1 255.255.255.252
R10(config)# router ospf 46
R10(config-router)# network 10.3.0.0 0.0.255.255 area 3
```

R10 的 OSPF 数据库：观察可知，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 46)

                Router Link States (Area 3)

Link ID         ADV Router      Age         Seq#       Checksum Link count
10.3.90.1       10.3.90.1       33          0x80000004 0x000E2C 1
10.3.100.1      10.3.100.1      32          0x80000002 0x0098E2 3

                Net Link States (Area 3)

Link ID         ADV Router      Age         Seq#       Checksum
10.3.0.1        10.3.90.1       32          0x80000001 0x004D9B
```

R10 的路由表：观察可知，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, 3 subnets, 2 masks
C       10.3.1.0/24 is directly connected, FastEthernet0/0
C       10.3.0.0/24 is directly connected, FastEthernet0/1
C       10.3.100.0/30 is directly connected, Loopback0
```

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（命令：area <area-id> virtual-link RID），这样 Area 3 就能和 Area 0 进行路由信息交换了。其中，area-id 写 1，RID 写对方的 Router ID，稍候查看虚链路建立情况（命令：show ip ospf virtual-links）和邻居信息（命令：show ip ospf neighbor）。

R4 配置命令：

```
R4(config)# router ospf 46
R4(config-router)# area 1 virtual-link 10.3.90.1
```

R9 配置命令：

```
R9(config)# router ospf 46
R9(config-router)# area 1 virtual-link 10.0.40.1
```

查看 R4 虚链路：观察得知，R4 通过区域 1 的接口 Fa0/1 与 R9（RID 是 10.3.90.1 ）建立了虚链路，使用的 Cost 值为 74 。

```
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 00:00:08
    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
```

查看 R9 虚链路：观察得知，R9 通过区域__1__的接口__Se0/0__与 R4（RID 是__10.0.40.1__）建立了虚链路，使用的 Cost 值为__74__。

```
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 00:00:08
    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
```

查看 R4 邻居信息：观察得知，R4 通过接口__OSPF_VL0__与 R9（RID 是__10.3.90.1__）建立了邻接关系。

```
R4#show ip ospf neighbor

Neighbor ID     Pri   State           Dead Time   Address         Interface
10.3.90.1         0   FULL/  -        -           10.1.2.4        OSPF_VL0
10.0.20.1         1   FULL/DROTHER    00:00:39    10.0.123.249    FastEthernet0/0
10.0.30.1         1   FULL/DR         00:00:30    10.0.123.250    FastEthernet0/0
10.0.60.1         1   FULL/DROTHER    00:00:30    10.0.123.252    FastEthernet0/0
10.1.50.1         1   FULL/BDR        00:00:36    10.1.0.2        FastEthernet0/1
```

查看 R9 邻居信息：观察得知，R9 通过接口__OSPF_VL0__与 R4（RID 是__10.0.40.1__）建立了邻接关系。

```
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/  -        00:01:59    10.1.2.2        Serial0/0
10.3.100.1        1   FULL/BDR        00:00:33    10.3.0.2        FastEthernet0/1
```

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

R10 的路由表：

```
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, 23 subnets, 4 masks
C       10.3.1.0/24 is directly connected, FastEthernet0/0
O IA    10.1.2.1/32 [110/74] via 10.3.0.1, 00:07:44, FastEthernet0/1
C       10.3.0.0/24 is directly connected, FastEthernet0/1
O IA    10.2.1.0/24 [110/104] via 10.3.0.1, 00:05:58, FastEthernet0/1
O IA    10.2.2.0/24 [110/105] via 10.3.0.1, 00:05:58, FastEthernet0/1
O IA    10.1.2.3/32 [110/138] via 10.3.0.1, 00:07:44, FastEthernet0/1
O IA    10.1.1.0/24 [110/84] via 10.3.0.1, 00:07:45, FastEthernet0/1
O IA    10.0.0.0/24 [110/114] via 10.3.0.1, 00:06:00, FastEthernet0/1
O IA    10.2.3.0/24 [110/114] via 10.3.0.1, 00:06:00, FastEthernet0/1
O IA    10.1.2.2/32 [110/74] via 10.3.0.1, 00:07:45, FastEthernet0/1
O IA    10.1.0.0/24 [110/84] via 10.3.0.1, 00:07:45, FastEthernet0/1
O IA    10.0.1.0/24 [110/104] via 10.3.0.1, 00:06:00, FastEthernet0/1
O IA    10.1.2.4/32 [110/10] via 10.3.0.1, 00:07:46, FastEthernet0/1
O IA    10.0.20.1/32 [110/95] via 10.3.0.1, 00:06:01, FastEthernet0/1
O IA    10.0.40.1/32 [110/85] via 10.3.0.1, 00:06:02, FastEthernet0/1
O IA    10.0.60.1/32 [110/95] via 10.3.0.1, 00:06:02, FastEthernet0/1
O IA    10.1.50.1/32 [110/75] via 10.3.0.1, 00:07:48, FastEthernet0/1
O IA    10.1.70.1/32 [110/139] via 10.3.0.1, 00:07:48, FastEthernet0/1
O IA    10.2.80.1/32 [110/105] via 10.3.0.1, 00:06:03, 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, 00:06:03, FastEthernet0/1
O IA    10.0.123.244/30 [110/104] via 10.3.0.1, 00:06:03, FastEthernet0/1
O IA    10.0.123.248/29 [110/94] via 10.3.0.1, 00:06:03, FastEthernet0/1
```

R10 的 OSPF 数据库：观察得知，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 ospf database

            OSPF Router with ID (10.3.100.1) (Process ID 46)

                Router Link States (Area 3)

Link ID         ADV Router      Age         Seq#       Checksum Link count
10.3.90.1       10.3.90.1       33          0x80000004 0x000E2C 1
10.3.100.1      10.3.100.1      32          0x80000002 0x0098E2 3

                Net Link States (Area 3)

Link ID         ADV Router      Age         Seq#       Checksum
10.3.0.1        10.3.90.1       32          0x80000001 0x004D9B
R10#show ip ospf database

            OSPF Router with ID (10.3.100.1) (Process ID 46)

                Router Link States (Area 3)

Link ID         ADV Router      Age         Seq#       Checksum Link count
10.3.90.1       10.3.90.1       429         0x80000005 0x000F29 1
10.3.100.1      10.3.100.1      725         0x80000002 0x0098E2 3

                Net Link States (Area 3)

Link ID         ADV Router      Age         Seq#       Checksum
10.3.0.1        10.3.90.1       726         0x80000001 0x004D9B

                Summary Net Link States (Area 3)

Link ID         ADV Router      Age         Seq#       Checksum
10.0.0.0        10.3.90.1       318         0x80000001 0x002A38
10.0.1.0        10.3.90.1       318         0x80000001 0x00BAB0
10.0.20.1       10.3.90.1       318         0x80000001 0x0084DB
10.0.40.1       10.3.90.1       318         0x80000001 0x004313
10.0.60.1       10.3.90.1       318         0x80000001 0x00CA6D
10.0.123.240    10.3.90.1       318         0x80000001 0x001AB2
10.0.123.244    10.3.90.1       318         0x80000001 0x00D32B
10.0.123.248    10.3.90.1       320         0x80000001 0x002FD9
10.1.0.0        10.3.90.1       431         0x80000001 0x00F08E
10.1.1.0        10.3.90.1       431         0x80000001 0x00E598
10.1.2.1        10.3.90.1       432         0x80000001 0x006C1A
10.1.2.2        10.3.90.1       432         0x80000001 0x006223
10.1.2.3        10.3.90.1       432         0x80000001 0x00DA69
10.1.2.4        10.3.90.1       432         0x80000001 0x00CBF7
10.1.50.1       10.3.90.1       432         0x80000001 0x0064F0
10.1.70.1       10.3.90.1       432         0x80000001 0x000AF6
10.2.1.0        10.3.90.1       321         0x80000001 0x00A2C6
10.2.2.0        10.3.90.1       321         0x80000001 0x00A1C5
10.2.3.0        10.3.90.1       321         0x80000001 0x00F06C
10.2.80.1       10.3.90.1       321         0x80000001 0x003ADD
```

31. 在 R9 上手工合并 Area 0 上的子网路由（命令：area 0 range <ip_net> <mask>，其中 ip_net 写成 10.0.0.0，mask 写成 255.255.0.0，表示 10.0.x.x 这些网络都在 area 0 上），然后显示 R9 和 R10 的路由表，看看所指定的子网是否合并了路由

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。

```
R9#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, 24 subnets, 5 masks
O       10.3.1.0/24 [110/20] via 10.3.0.2, 00:00:19, FastEthernet0/1
O       10.1.2.1/32 [110/64] via 10.1.2.2, 00:00:19, Serial0/0
C       10.3.0.0/24 is directly connected, FastEthernet0/1
O IA    10.2.1.0/24 [110/94] via 10.1.2.2, 00:00:19, Serial0/0
C       10.1.2.0/24 is directly connected, Serial0/0
O IA    10.2.2.0/24 [110/95] via 10.1.2.2, 00:00:19, Serial0/0
O       10.1.2.3/32 [110/128] via 10.1.2.2, 00:00:19, Serial0/0
O       10.1.1.0/24 [110/74] via 10.1.2.2, 00:00:20, Serial0/0
O       10.0.0.0/24 [110/104] via 10.1.2.2, 00:00:20, Serial0/0
O       10.0.0.0/16 is a summary, 00:00:20, Null0
O IA    10.2.3.0/24 [110/104] via 10.1.2.2, 00:00:20, Serial0/0
O       10.1.2.2/32 [110/64] via 10.1.2.2, 00:00:20, Serial0/0
O       10.1.0.0/24 [110/74] via 10.1.2.2, 00:00:23, Serial0/0
O       10.0.1.0/24 [110/94] via 10.1.2.2, 00:00:24, Serial0/0
O       10.0.20.1/32 [110/85] via 10.1.2.2, 00:00:24, Serial0/0
O       10.0.40.1/32 [110/75] via 10.1.2.2, 00:00:24, Serial0/0
O       10.0.60.1/32 [110/85] via 10.1.2.2, 00:00:25, Serial0/0
O       10.1.50.1/32 [110/65] via 10.1.2.2, 00:00:25, Serial0/0
O       10.1.70.1/32 [110/129] via 10.1.2.2, 00:00:25, Serial0/0
O IA    10.2.80.1/32 [110/95] via 10.1.2.2, 00:00:26, Serial0/0
O       10.3.100.1/32 [110/11] via 10.3.0.2, 00:00:26, FastEthernet0/1
O       10.0.123.240/30 [110/148] via 10.1.2.2, 00:00:26, Serial0/0
O       10.0.123.244/30 [110/94] via 10.1.2.2, 00:00:27, Serial0/0
O       10.0.123.248/29 [110/84] via 10.1.2.2, 00:00:27, Serial0/0
```

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。

```
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, 16 subnets, 4 masks
C       10.3.1.0/24 is directly connected, FastEthernet0/0
O IA    10.1.2.1/32 [110/74] via 10.3.0.1, 00:12:24, FastEthernet0/1
C       10.3.0.0/24 is directly connected, FastEthernet0/1
O IA    10.2.1.0/24 [110/104] via 10.3.0.1, 00:10:38, FastEthernet0/1
O IA    10.2.2.0/24 [110/105] via 10.3.0.1, 00:10:38, FastEthernet0/1
O IA    10.1.2.3/32 [110/138] via 10.3.0.1, 00:12:24, FastEthernet0/1
O IA    10.1.1.0/24 [110/84] via 10.3.0.1, 00:12:25, FastEthernet0/1
O IA    10.0.0.0/16 [110/85] via 10.3.0.1, 00:02:19, FastEthernet0/1
O IA    10.2.3.0/24 [110/114] via 10.3.0.1, 00:10:39, FastEthernet0/1
O IA    10.1.2.2/32 [110/74] via 10.3.0.1, 00:12:25, FastEthernet0/1
O IA    10.1.0.0/24 [110/84] via 10.3.0.1, 00:12:25, FastEthernet0/1
O IA    10.1.2.4/32 [110/10] via 10.3.0.1, 00:12:25, FastEthernet0/1
O IA    10.1.50.1/32 [110/75] via 10.3.0.1, 00:12:25, FastEthernet0/1
O IA    10.1.70.1/32 [110/139] via 10.3.0.1, 00:12:26, FastEthernet0/1
O IA    10.2.80.1/32 [110/105] via 10.3.0.1, 00:10:40, FastEthernet0/1
C       10.3.100.0/30 is directly connected, Loopback0
```

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，每个设备一个文件，分别命名为 R1.txt、R2.txt 等，随实验报告一起打包上传。

六、 实验结果与分析

根据你观察到的实验数据和对实验原理的理解，分别解答以下问题：

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

  同一网络的 OSPF 进程号可以不一样，路由通过不同进程号学习到不同的路由信息最后的效果是一样的。同时同一路由上面可以有多个进程号。

  但是为了防止混淆，还是设置成一样的吧。

- 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？

  未手工指定 Router ID 时，如果没有给回环接口配置 IP 地址，会从串口选取地址作为路由器 ID，路由器上的最高 IP 地址将成为此路由器的路由器 ID。如果给回环接口配置了 IP 地址，会从回环接口选取地址作为路由器 ID。

- 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？

  如果可选，会自动重新选择。

- 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，是通配符掩码，是掩码的反码。

- 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？

  是的。

  虚连接是设置在两个路由器之间，这两个路由器都有一个端口与同一个非主干区域相

连。虚连接被认为是属于主干区域的，在 OSPF 路由协议看来，虚连接两端的两个路由器被一个点对点的链路连接在一起。在 OSPF 路由协议中，通过虚连接的路由信息是作为域内路由来看待的。作用是模拟邻居节点传递路由表。从具体表现来看，虚连接能够把没有直接物理连接到主干的区域连接到主干并能在区域 0 不连续的情况下，对它进行修补。

- 为什么要在区域边界路由器上进行路由合并？

在区域边界路由器上进行路由合并能够减少路由表信息，方便路由进行寻找操作。

七、 讨论、心得

在完成本实验后，你可能会有很多待解答的问题，你可以把它们记在这里，接下来的学习中，你也许会逐渐得到答案的，同时也可以让老师了解到你有哪些困惑，老师在课堂可以安排针对性地解惑。等到课程结束后，你再回头看看这些问题时你或许会有不同的见解：

在实验过程中你可能会遇到的困难，并得到了宝贵的经验教训，请把它们记录下来，提供给其他人参考吧：

你对本实验安排有哪些更好的建议呢？欢迎献计献策：