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

姓　　名：应承峻

学　　院：计算机学院

系：计算机系

专　　业：软件工程

学　　号：3170103456

指导教师：高艺

2019 年 11 月 19 日

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

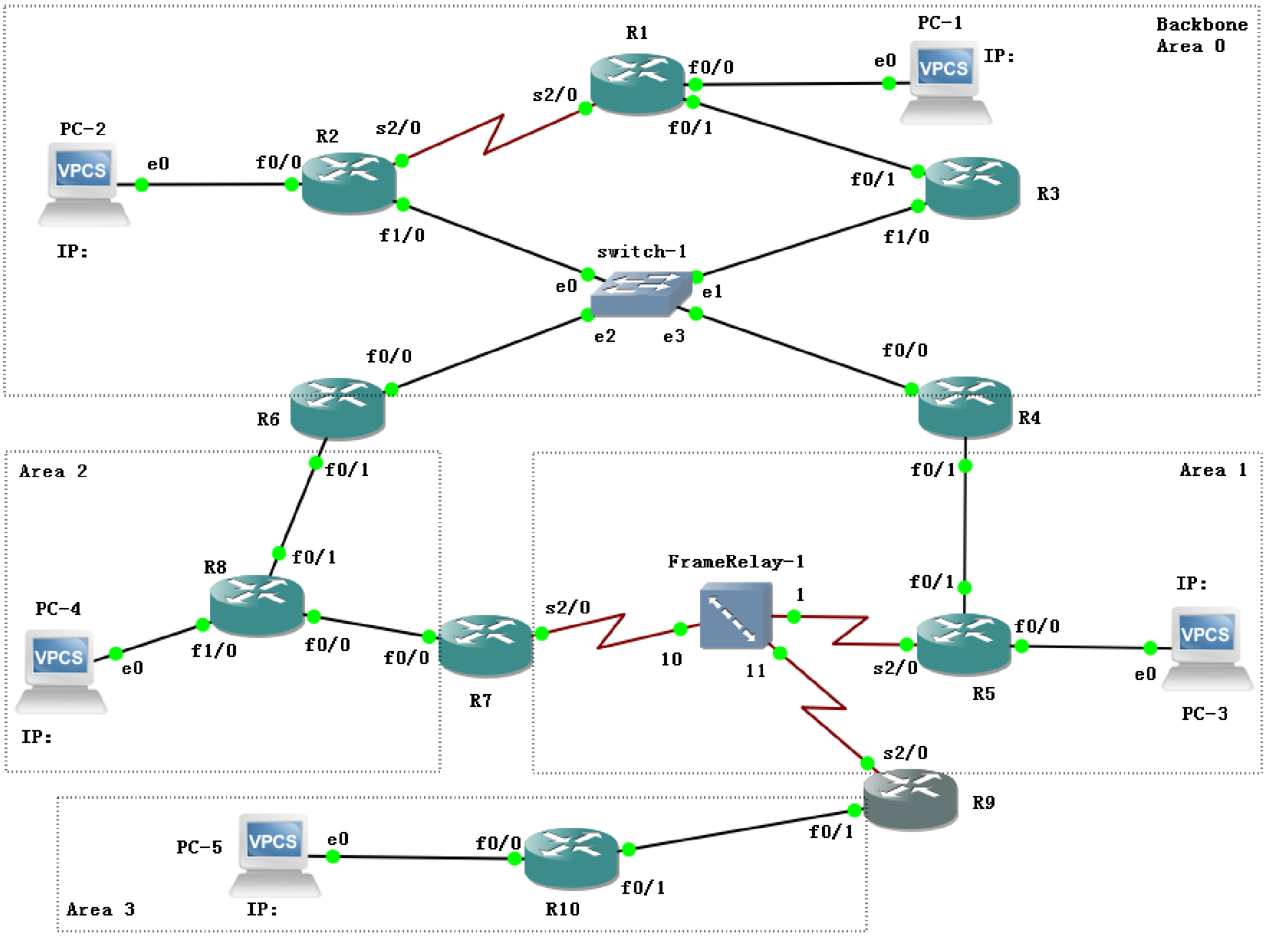
- 按照拓扑图连接 PC 和路由器，其中 R1-R2 之间采用串口连接，数据链路层协议使用 HDLC；R5、R7、R8 之间采用 Frame Relay 交换机连接（Frame Relay 交换机的配置请参考 GNS3 指南）。
- 设计好 PC 和路由器各端口的 IP 地址、子网掩码。分配地址时请遵循下面的规则：
  a) Area 0 使用 10.0.0.0/16 的网络地址进行扩展，每个子网分别使用 10.0.0.0/24、10.0.1.0/24、10.0.2.0/24 等子网地址。其中点对点连接的路由器之间的子网使用 10.0.123.240/28 进行扩展，可以最大程度的节约地址，例如使用串行掩码方案，网络地址部分为 30 位，每个子网刚好有 2 个可用地址（去掉 1 个主机地址部分全 0 的和 1 个主机地址部分全 1 的）， 可以按如下方式进行分配：

     R1-R2 互联接口：10.0.123.241/30、10.0.123.242/30，子网地址：10.0.123.240/30;

R1-R3 互联接口：10.0.123.245/30、10.0.123.246/30，子网地址：10.0.123.244/30；

依次类推，R2、R3、R4、R6 之间的子网为（只需要 4 个地址）：10.0.123.248/29，去掉全 0 全 1 地址后，还有 6 个地址可用。

b) Area 1、Area 2、Area 3 使用 10.X.0.0/16 的网络地址进行扩展，其中 X 为 Area 编号，例如 Area 1 的 3 个子网分别使用 10.1.0.0/24、10.1.1.0/24、10.1.2.0/24 等子网地址（同一个交换机上的多台路由器的接口属于同一个子网）。



- 配置各 PC 的的默认网关，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（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）；
- 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 之间的联通性；
- 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 间的联通性；

RIP 相关命令参考

- 在路由器上启用 RIP 协议

  `Router(config)# router rip`

  将路由器各接口（子网）加入路由宣告：

  `Router(config-router)# network <ip_net>`

OSPF 相关命令参考

- 给路由器的回环接口配置地址

  `Router(config)# interface loopback 0`

  `Router(config-if)# ip address <ip> <mask>`

- 在路由器上启用 OSPF 协议

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

- 配置路由器接口（子网）所属 Area ID

  `Router(config-router)# network <ip_net> <mask> area <area-id>`

- 查看路由器的 OSPF 数据库（可以查看 Router ID）

  `Router# show ip ospf database`

- 手工指定 Router ID

  `Router(config-router)# router-id x.x.x.x`

  更换 Router ID 需要重启路由器或清除 OSPF 状态才能生效，其中

  重启路由器命令：

  `Router# reload`

  清除 OSPF 状态命令：

  `Router# clear ip ospf process`

- 观察各路由器的 OSPF 邻居关系，在广播网络中，为减少通信量，会自动选出一个 DR（Designated Router）和一个 BDR（Backup Designated Router），其他路由器只与 DR、BDR 成为邻接关系。

  `Router# show ip ospf neighbor detail`

- 观察路由器的 OSPF 接口状态（可以查看 cost 值）

  `Router# show ip ospf interface`

- 打开事件调试，实时显示路由器之间交换的路由信息事件

  `Router# debug ip ospf events`

  观察完毕后，可以关闭调试信息显示：

  `Router# no debug ip ospf events`

- 在两个区域边界路由器之间建立虚链路，<area-id>填写用于传递数据的区域 ID，<router ID>分别设为对方的 Router ID：

  `Router(config-router)# area <area-id> virtual-link <router ID>`

- 在区域边界路由器上手工进行路由合并：

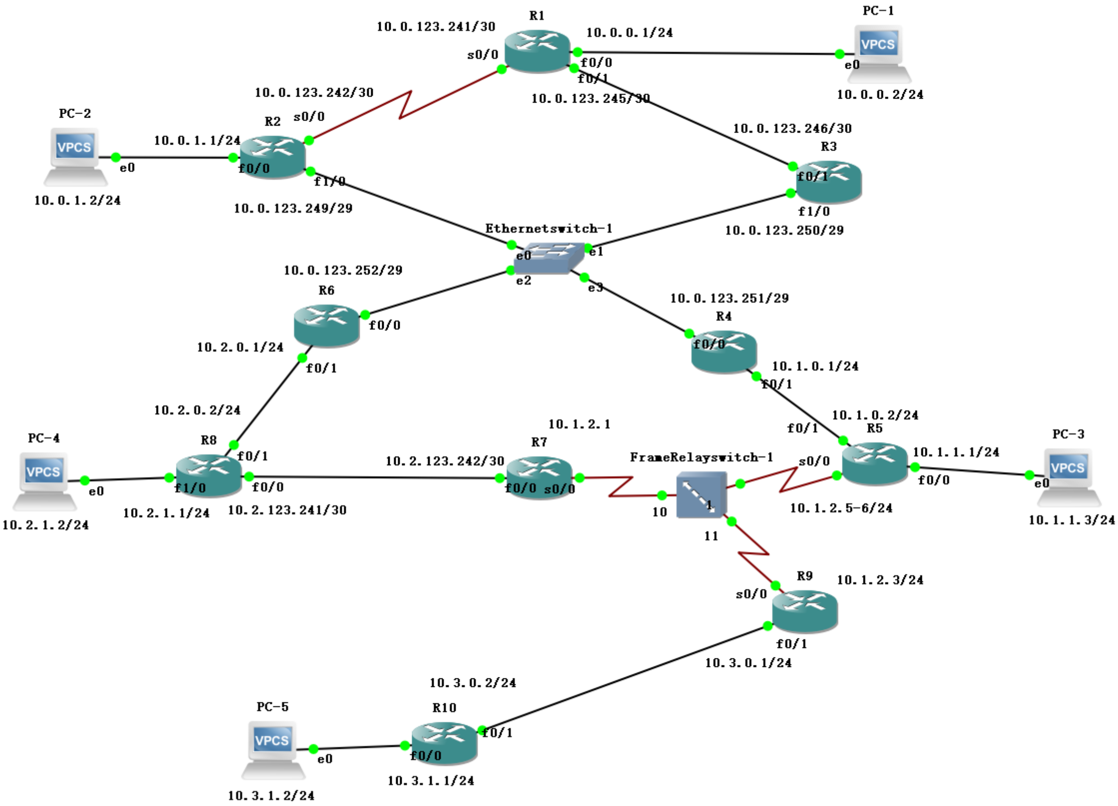
  `Router(config-router)# area <area-id> range <ip_net> <mask>`

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）：

conf t
interface f0/0
ip addr 10.0.0.1 255.255.255.0
no shutdown
exit
interface f0/1
ip addr 10.0.123.245 255.255.255.252
no shutdown
exit
interface s0/0
ip addr 10.0.123.241 255.255.255.252

encapsulation hdlc

clock rate 128000

no shutdown

exit

exit

write

```
R1(config)#interface f0/0
R1(config-if)#ip addr 10.0.0.1 255.255.255.0
R1(config-if)#no shutdown
R1(config-if)#exit
R1(config)#interface f0/1
R1(config-if)#ip addr 10.0.123.245 255.255.255.252
R1(config-if)#no shutdown
R1(config-if)#exit
R1(config)#interface s0/0
R1(config-if)#ip addr 10.0.123.241 255.255.255.252
R1(config-if)#encapsulation hdlc
R1(config-if)#clock rate 128000
R1(config-if)#no shutdown
R1(config-if)#exit
```

R2 配置命令：

conf t

interface f0/0

ip addr 10.0.1.1 255.255.255.0

no shutdown

exit

interface f1/0

ip addr 10.0.123.249 255.255.255.248

no shutdown

exit

interface s0/0

ip addr 10.0.123.242 255.255.255.252

encapsulation hdlc

no shutdown

exit

exit

write

```
R2(config)#interface f0/0
R2(config-if)#ip addr 10.0.1.1 255.255.255.0
R2(config-if)#no shutdown
R2(config-if)#exit
R2(config)#interface f1/0
R2(config-if)#ip addr 10.0.123.249 255.255.255.248
R2(config-if)#no shutdown
R2(config-if)#exit
R2(config)#interface s0/0
R2(config-if)#ip addr 10.0.123.242 255.255.255.252
R2(config-if)#encapsulation hdlc
R2(config-if)#no shutdown
R2(config-if)#exit
R2(config)#exit
R2#write
```

R3 配置命令：

conf t

interface f0/1

ip addr 10.0.123.246 255.255.255.252

no shutdown

exit

interface f1/0

ip addr 10.0.123.250 255.255.255.248

no shutdown

exit

exit

write

```
R3#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R3(config)#interface f0/1
R3(config-if)#ip addr 10.0.123.246 255.255.255.252
R3(config-if)#no shutdown
R3(config-if)#exit
R3(config)#interface f1/0
R3(config-if)#ip addr 10.0.123.250 255.255.255.248
R3(config-if)#no shutdown
R3(config-if)#exit
R3(config)#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=16.779 ms
84 bytes from 10.0.0.1 icmp_seq=2 ttl=255 time=17.762 ms
84 bytes from 10.0.0.1 icmp_seq=3 ttl=255 time=12.864 ms
84 bytes from 10.0.0.1 icmp_seq=4 ttl=255 time=16.303 ms
84 bytes from 10.0.0.1 icmp_seq=5 ttl=255 time=2.283 ms
```

PC2→R2:

```
PC-2> ping 10.0.1.1
84 bytes from 10.0.1.1 icmp_seq=1 ttl=255 time=15.877 ms
84 bytes from 10.0.1.1 icmp_seq=2 ttl=255 time=18.332 ms
84 bytes from 10.0.1.1 icmp_seq=3 ttl=255 time=32.643 ms
84 bytes from 10.0.1.1 icmp_seq=4 ttl=255 time=15.173 ms
84 bytes from 10.0.1.1 icmp_seq=5 ttl=255 time=30.828 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）;

router rip

version 2

network 10.0.0.0

exit

exit

write

R1 配置命令：

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

R2 配置命令：

```
R2#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R2(config)#router rip
R2(config-router)#version 2
R2(config-router)#network 10.0.0.0
R2(config-router)#exit
R2(config)#exit
R2#write
```

R3 配置命令：

```
R3#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R3(config)#router rip
R3(config-router)#version 2
R3(config-router)#network 10.0.0.0
R3(config-router)#exit
R3(config)#exit
R3#write
```

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, 00:00:17, 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, 00:00:21, FastEthernet0/1
                        [120/1] via 10.0.123.242, 00:00:17, Serial0/0
R1#
```

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, 00:00:22, 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, 00:00:19, FastEthernet1/0
                        [120/1] via 10.0.123.241, 00:00:22, Serial0/0
C       10.0.123.248/29 is directly connected, FastEthernet1/0
R2#
```

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, 00:00:06, FastEthernet1/0
R       10.0.123.240/30 [120/1] via 10.0.123.249, 00:00:06, 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
R3#
```

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    9.738 ms  9.041 ms  9.078 ms
 2   10.0.123.242   9.658 ms  10.446 ms  9.447 ms
 3     *  *  *
 4   *10.0.1.2   14.683 ms (ICMP type:3, code:3, Destination port unreachable)
```

---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:

router ospf 56

network 10.0.0.0 0.0.255.255 area 0

```
R1(config)#router ospf 56
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:

inter loopback 0

ip addr 10.0.20.1 255.255.255.252

exit

router ospf 56

network 10.0.0.0 0.0.255.255 area 0

```
R2(config)#inter loopback 0
R2(config-if)#ip addr 10.0.20.1 255.255.255.252
R2(config-if)#exit
R2(config)#router ospf 56
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：

conf t

router ospf 56

router-id 10.0.30.1

network 10.0.0.0 0.0.255.255 area 0

```
R3(config)#router ospf 56
R3(config-router)#router-id 10.0.30.1
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 OSPF 数据库：

```
R1#sh ip ospf database

            OSPF Router with ID (10.0.123.245) (Process ID 56)

                Router Link States (Area 0)

Link ID         ADV Router      Age         Seq#       Checksum Link count
10.0.20.1       10.0.20.1       110         0x80000002 0x00E5B3 5
10.0.30.1       10.0.30.1       107         0x80000002 0x003D91 2
10.0.123.245    10.0.123.245    109         0x80000003 0x001756 4

                Net Link States (Area 0)

Link ID         ADV Router      Age         Seq#       Checksum
10.0.123.245    10.0.123.245    109         0x80000001 0x00DFC1
10.0.123.249    10.0.20.1       110         0x80000001 0x00FC5D
R1#
```

从上图可知，R1 的 Router ID 为 10.0.123.245 （取自接口 f0/1 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#sh ip ospf database

            OSPF Router with ID (10.0.20.1) (Process ID 56)

                Router Link States (Area 0)

Link ID         ADV Router      Age         Seq#       Checksum Link count
10.0.20.1       10.0.20.1       365         0x80000002 0x00E5B3 5
10.0.30.1       10.0.30.1       363         0x80000002 0x003D91 2
10.0.123.245    10.0.123.245    366         0x80000003 0x001756 4

                Net Link States (Area 0)

Link ID         ADV Router      Age         Seq#       Checksum
10.0.123.245    10.0.123.245    366         0x80000001 0x00DFC1
10.0.123.249    10.0.20.1       365         0x80000001 0x00FC5D
R2#
```

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#sh ip ospf database

            OSPF Router with ID (10.0.30.1) (Process ID 56)

                Router Link States (Area 0)

Link ID         ADV Router      Age         Seq#       Checksum Link count
10.0.20.1       10.0.20.1       372         0x80000002 0x00E5B3 5
10.0.30.1       10.0.30.1       366         0x80000002 0x003D91 2
10.0.123.245    10.0.123.245    372         0x80000003 0x001756 4

                Net Link States (Area 0)

Link ID         ADV Router      Age         Seq#       Checksum
10.0.123.245    10.0.123.245    371         0x80000001 0x00DFC1
10.0.123.249    10.0.20.1       372         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 s2/0：（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 56, 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 00:00:00
  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 4 msec, maximum is 4 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 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#show ip ospf interface
FastEthernet0/1 is up, line protocol is up
  Internet Address 10.0.123.245/30, Area 0
  Process ID 56, 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 00:00:02
  Supports Link-local Signaling (LLS)
  Index 3/3, flood queue length 0
  Next 0x0(0)/0x0(0)
  Last flood scan length is 0, 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 10.0.30.1  (Backup Designated Router)
  Suppress hello for 0 neighbor(s)
```

R1 的 f0/0:（f0/1 连接的网络类型为 broadcast ，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 56, 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 00:00:00
  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, 00:25:33, FastEthernet0/1
R       10.0.20.0/30 [120/1] via 10.0.123.242, 00:00:22, Serial0/0
O       10.0.20.1/32 [110/12] via 10.0.123.246, 00:25:33, 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, 00:25:35, FastEthernet0/1
R1#
```

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, 00:27:51, 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, 00:27:51, FastEthernet1/0
C       10.0.123.248/29 is directly connected, FastEthernet1/0
R2#
```

R3 路由表：

```
     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, 00:27:46, FastEthernet0/1
O       10.0.1.0/24 [110/11] via 10.0.123.249, 00:27:46, FastEthernet1/0
R       10.0.20.0/30 [120/1] via 10.0.123.249, 00:00:12, FastEthernet1/0
O       10.0.20.1/32 [110/2] via 10.0.123.249, 00:27:46, FastEthernet1/0
O       10.0.123.240/30 [110/65] via 10.0.123.249, 00:27:46, FastEthernet1/0
C       10.0.123.244/30 is directly connected, FastEthernet0/1
C       10.0.123.248/29 is directly connected, FastEthernet1/0
R3#
```

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    9.530 ms  8.050 ms  10.264 ms
 2   10.0.123.246   30.323 ms  31.150 ms  31.198 ms
 3   10.0.123.249   51.483 ms  52.021 ms  40.586 ms
 4     **10.0.1.2   47.876 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, 00:00:02, Serial0/0
R       10.0.20.0/30 [120/1] via 10.0.123.242, 00:00:12, Serial0/0
O       10.0.20.1/32 [110/65] via 10.0.123.242, 00:00:02, 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, 00:00:02, Serial0/0
R1#
```

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__s0/0__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 56)

                Router Link States (Area 0)

Link ID         ADV Router      Age         Seq#       Checksum Link count
10.0.20.1       10.0.20.1       33          0x80000004 0x005942 5
10.0.30.1       10.0.30.1       113         0x80000008 0x00DC6B 2
10.0.123.241    10.0.123.241    24          0x80000002 0x004442 3
10.0.123.245    10.0.123.245    146         0x80000009 0x00F581 3

                Net Link States (Area 0)

Link ID         ADV Router      Age         Seq#       Checksum
10.0.123.249    10.0.20.1       471         0x80000002 0x00FA5E
R1#
```

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__）

```
R1(config-if)#no shutdown
R1(config-if)#exit
R1(config)#exit
*Mar  1 00:00:18.147: OSPF: Interface FastEthernet0/1 going Up
*Mar  1 00:00:18.147: OSPF: Send hello to 224.0.0.5 area 0 on FastEthernet0/1 from 10.0.123.245
*Mar  1 00:00:18.159: OSPF: Rcv hello from 10.0.30.1 area 0 from FastEthernet0/1 10.0.123.246
*Mar  1 00:00:18.159: OSPF: 2 Way Communication to 10.0.30.1 on FastEthernet0/1, state 2WAY
*Mar  1 00:00:18.163: OSPF: Backup seen Event before WAIT timer on FastEthernet0/1
*Mar  1 00:00:18.163: OSPF: DR/BDR election on FastEthernet0/1
*Mar  1 00:00:18.163: OSPF: Elect BDR 10.0.123.241
*Mar  1 00:00:18.163: OSPF: Elect DR 10.0.30.1
*Mar  1 00:00:18.163: OSPF: Elect BDR 10.0.123.241
R1(config)#exit
*Mar  1 00:00:18.163: OSPF: Elect DR 10.0.30.1
*Mar  1 00:00:18.167:        DR: 10.0.30.1 (Id)   BDR: 10.0.123.241 (Id)
*Mar  1 00:00:18.167: OSPF: Send DBD to 10.0.30.1 on FastEthernet0/1 seq 0x156 opt 0x52 flag 0x7 len 32
*Mar  1 00:00:18.167: OSPF: Send immediate hello to nbr 10.0.30.1, src address 10.0.123.246, on FastEthernet0/
1
*Mar  1 00:00:18.171: OSPF: Send hello to 10.0.123.246 area 0 on FastEthernet0/1 from 10.0.123.245
*Mar  1 00:00:18.171: OSPF: End of hello processing
*Mar  1 00:00:18.715: OSPF: Rcv LS UPD from 10.0.20.1 on Serial0/0 length 76 LSA count 1
*Mar  1 00:00:18.759: OSPF: Rcv LS UPD from 10.0.20.1 on Serial0/0 length 60 LSA count 1
R1(config)#exit
*Mar  1 00:00:20.127: %LINK-3-UPDOWN: Interface FastEthernet0/1, changed state to up
*Mar  1 00:00:21.127: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet0/1, changed state to up
R1(config)#exit
R1#
*Mar  1 00:00:22.139: %SYS-5-CONFIG_I: Configured from console by console
R1#
*Mar  1 00:00:22.375: OSPF: Rcv hello from 10.0.30.1 area 0 from FastEthernet0/1 10.0.123.246
*Mar  1 00:00:22.375: OSPF: End of hello processing
*Mar  1 00:00:23.167: OSPF: Send DBD to 10.0.30.1 on FastEthernet0/1 seq 0x156 opt 0x52 flag 0x7 len 32
*Mar  1 00:00:23.167: OSPF: Retransmitting DBD to 10.0.30.1 on FastEthernet0/1 [1]
*Mar  1 00:00:23.207: OSPF: Rcv DBD from 10.0.30.1 on FastEthernet0/1 seq 0xC6 opt 0x52 flag 0x7 len 32  mtu 1
```

```
R1#
*Mar  1 00:00:22.139: %SYS-5-CONFIG_I: Configured from console by console
R1#
*Mar  1 00:00:22.375: OSPF: Rcv hello from 10.0.30.1 area 0 from FastEthernet0/1 10.0.123.246
*Mar  1 00:00:22.375: OSPF: End of hello processing
*Mar  1 00:00:23.167: OSPF: Send DBD to 10.0.30.1 on FastEthernet0/1 seq 0x156 opt 0x52 flag 0x7 len 32
*Mar  1 00:00:23.167: OSPF: Retransmitting DBD to 10.0.30.1 on FastEthernet0/1 [1]
*Mar  1 00:00:23.207: OSPF: Rcv DBD from 10.0.30.1 on FastEthernet0/1 seq 0xC6 opt 0x52 flag 0x7 len 32  mtu 1
500 state EXSTART
*Mar  1 00:00:23.207: OSPF: First DBD and we are not SLAVE
*Mar  1 00:00:23.215: OSPF: Rcv DBD from 10.0.30.1 on FastEthernet0/1 seq 0x156 opt 0x52 flag 0x2 len 132  mtu
 1500 state EXSTART
*Mar  1 00:00:23.215: OSPF: NBR Negotiation Done. We are the MASTER
*Mar  1 00:00:23.215: OSPF: Send DBD to 10.0.30.1 on FastEthernet0/1 seq 0x157 opt 0x52 flag 0x3 len 132
*Mar  1 00:00:23.227: OSPF: Rcv DBD from 10.0.30.1 on FastEthernet0/1 seq 0x157 opt 0x52 flag 0x0 len 32  mtu
1500 state EXCHANGE
*Mar  1 00:00:23.227: OSPF: Send DBD to 10.0.30.1 on FastEthernet0/1 seq 0x158 opt 0x52 flag 0x1 len 32
*Mar  1 00:00:23.235: OSPF: Rcv DBD from 10.0.30.1 on FastEthernet0/1 seq 0x158 opt 0x52 flag 0x0 len 32  mtu
1500 state EXCHANGE
*Mar  1 00:00:23.235: OSPF: Exchange Done with 10.0.30.1 on FastEthernet0/1
*Mar  1 00:00:23.235: OSPF: Synchronized with 10.0.30.1 on FastEthernet0/1, state FULL
*Mar  1 00:00:23.235: %OSPF-5-ADJCHG: Process 56, Nbr 10.0.30.1 on FastEthernet0/1 from LOADING to FULL, Loadi
ng Done
*Mar  1 00:00:23.247: OSPF: Rcv hello from 10.0.20.1 area 0 from Serial0/0 10.0.123.242
*Mar  1 00:00:23.247: OSPF: End of hello processing
*Mar  1 00:00:23.751: OSPF: Rcv LS UPD from 10.0.30.1 on FastEthernet0/1 length 76 LSA count 1
*Mar  1 00:00:23.751: OSPF: Rcv LS UPD from 10.0.20.1 on Serial0/0 length 76 LSA count 1
*Mar  1 00:00:23.755: OSPF: Rcv LS UPD from 10.0.30.1 on FastEthernet0/1 length 60 LSA count 1
*Mar  1 00:00:23.787: OSPF: Rcv LS UPD from 10.0.20.1 on Serial0/0 length 60 LSA count 1
*Mar  1 00:00:24.587: OSPF: Send hello to 224.0.0.5 area 0 on FastEthernet0/0 from 10.0.0.1
*Mar  1 00:00:24.763: OSPF: Send hello to 224.0.0.5 area 0 on Serial0/0 from 10.0.123.241
*Mar  1 00:00:25.115: OSPF: Rcv LS UPD from 10.0.30.1 on FastEthernet0/1 length 100 LSA count 1
```

R1 的 OSPF 邻居详细信息：

```
R1#sh 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 10.0.123.246 BDR is 10.0.123.245
    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 00:00:35
    Neighbor is up for 00:03:48
    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, 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 O-bit)
    LLS Options is 0x1 (LR)
    Dead timer due in 00:00:36
    Neighbor is up for 00:04:03
    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
```

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：

conf t
inter f0/0
ip addr 10.0.123.251 255.255.255.248
no shut
exit
inter loopback 0
ip addr 10.0.40.1 255.255.255.252
no shut
exit
router ospf 56
network 10.0.0.0 0.0.255.255 area 0
exit
exit

R6 配置命令：

conf t
inter f0/0
ip addr 10.0.123.252 255.255.255.248

no shut

exit

inter loopback 0

ip addr 10.0.60.1 255.255.255.252

no shut

exit

router ospf 56

network 10.0.0.0 0.0.255.255 area 0

exit

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）：

```
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        00:00:36    10.0.123.250    FastEthernet0/0
10.0.60.1         1   2WAY/DROTHER    00:00:31    10.0.123.252    FastEthernet0/0
R4#
```

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#sh ip ospf neighbor

Neighbor ID     Pri   State           Dead Time   Address         Interface
10.0.20.1         1   FULL/DR         00:00:35    10.0.123.249    FastEthernet0/0
10.0.30.1         1   FULL/BDR        00:00:34    10.0.123.250    FastEthernet0/0
10.0.40.1         1   2WAY/DROTHER    00:00:33    10.0.123.251    FastEthernet0/0
R6#
```

---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）：

conf t
inter f0/1
ip addr 10.1.0.1 255.255.255.0
no shut
exit
router ospf 56
network 10.1.0.0 0.0.255.255 area 1

R5 配置命令：

R5(config)#interface f0/1

R5(config-if)# ip addr 10.1.0.2 255.255.255.0

R5(config-if)# no shut

R5(config)#interface f0/0

R5(config-if)# ip addr 10.1.1.1 255.255.255.0

R5(config-if)# __no shut__

R5(config)#interface loopback 0

R5(config-if)# __ip addr 10.1.50.1 255.255.255.252__

R5(config)# __router ospf 56__

R5(config-router)# __network 10.1.0.0 0.0.255.255 area 1__

PC3 配置命令：

```
PC-3> ip 10.1.1.3 255.255.255.0 10.1.1.1
Checking for duplicate address...
PC1 : 10.1.1.3 255.255.255.0 gateway 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__f1/0__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, 00:05:29, FastEthernet1/0
O       10.0.0.0/24 [110/21] via 10.0.123.250, 00:17:48, FastEthernet1/0
O IA    10.1.0.0/24 [110/11] via 10.0.123.251, 00:17:48, 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, 00:17:48, FastEthernet1/0
O       10.0.60.1/32 [110/2] via 10.0.123.252, 00:17:50, FastEthernet1/0
O IA    10.1.50.1/32 [110/12] via 10.0.123.251, 00:05:30, 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, 00:17:50, FastEthernet1/0
C       10.0.123.248/29 is directly connected, FastEthernet1/0
R2#
```

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__f0/1__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, 00:06:47, 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, 00:06:47, FastEthernet0/1
O IA    10.0.20.1/32 [110/21] via 10.1.0.1, 00:06:47, FastEthernet0/1
O IA    10.0.40.1/32 [110/11] via 10.1.0.1, 00:06:47, FastEthernet0/1
O IA    10.0.60.1/32 [110/21] via 10.1.0.1, 00:06:48, 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, 00:06:48, FastEthernet0/1
O IA    10.0.123.244/30 [110/30] via 10.1.0.1, 00:06:48, FastEthernet0/1
O IA    10.0.123.248/29 [110/20] via 10.1.0.1, 00:06:48, FastEthernet0/1
R5#
```

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=70.608 ms
84 bytes from 10.0.0.2 icmp_seq=3 ttl=60 time=77.389 ms
84 bytes from 10.0.0.2 icmp_seq=4 ttl=60 time=59.775 ms
84 bytes from 10.0.0.2 icmp_seq=5 ttl=60 time=68.202 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 56)

                Router Link States (Area 0)

Link ID         ADV Router      Age         Seq#       Checksum Link count
10.0.20.1       10.0.20.1       1514        0x80000002 0x00286E 5
10.0.30.1       10.0.30.1       1515        0x80000002 0x005B70 2
10.0.40.1       10.0.40.1       1348        0x80000003 0x00A0D7 2
10.0.60.1       10.0.60.1       1515        0x80000002 0x000538 2
10.0.123.245    10.0.123.245    1515        0x80000002 0x001955 4

                Net Link States (Area 0)

Link ID         ADV Router      Age         Seq#       Checksum
10.0.123.245    10.0.123.245    1515        0x80000001 0x00DFC1
10.0.123.252    10.0.60.1       1515        0x80000001 0x008527

                Summary Net Link States (Area 0)

Link ID         ADV Router      Age         Seq#       Checksum
10.1.0.0        10.0.40.1       1344        0x80000001 0x00E50F
10.1.1.0        10.0.40.1       604         0x80000001 0x003FAA
10.1.50.1       10.0.40.1       604         0x80000001 0x00BD03
R2#
```

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。

```
                Router Link States (Area 1)

Link ID         ADV Router      Age         Seq#       Checksum Link count
10.0.40.1       10.0.40.1       841         0x80000002 0x00B0F8 1
10.1.50.1       10.1.50.1       835         0x80000002 0x00DB42 3

                Net Link States (Area 1)

Link ID         ADV Router      Age         Seq#       Checksum
10.1.0.1        10.0.40.1       841         0x80000001 0x005C2D

                Summary Net Link States (Area 1)

Link ID         ADV Router      Age         Seq#       Checksum
10.0.0.0        10.0.40.1       1572        0x80000001 0x00BA27
10.0.1.0        10.0.40.1       1572        0x80000001 0x004B9F
10.0.20.1       10.0.40.1       1572        0x80000001 0x0015CA
10.0.40.1       10.0.40.1       1572        0x80000001 0x00D302
10.0.60.1       10.0.40.1       1572        0x80000001 0x005B5C
10.0.123.240    10.0.40.1       1572        0x80000001 0x00AAA1
10.0.123.244    10.0.40.1       1572        0x80000001 0x00641A
10.0.123.248    10.0.40.1       1574        0x80000001 0x00BFC8
R5#
```

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 。

```
R4#sh ip ospf database

            OSPF Router with ID (10.0.40.1) (Process ID 56)

                Router Link States (Area 0)

Link ID         ADV Router      Age         Seq#       Checksum Link count
10.0.20.1       10.0.20.1       138         0x80000003 0x00266F 5
10.0.30.1       10.0.30.1       152         0x80000003 0x005971 2
10.0.40.1       10.0.40.1       1936        0x80000003 0x00A0D7 2
10.0.60.1       10.0.60.1       147         0x80000003 0x000339 2
10.0.123.245    10.0.123.245    132         0x80000003 0x001756 4

                Net Link States (Area 0)

Link ID         ADV Router      Age         Seq#       Checksum
10.0.123.245    10.0.123.245    132         0x80000002 0x00DDC2
10.0.123.252    10.0.60.1       147         0x80000002 0x008328

                Summary Net Link States (Area 0)

Link ID         ADV Router      Age         Seq#       Checksum
10.1.0.0        10.0.40.1       1932        0x80000001 0x00E50F
10.1.1.0        10.0.40.1       1192        0x80000001 0x003FAA
10.1.50.1       10.0.40.1       1192        0x80000001 0x00BD03

                Router Link States (Area 1)

Link ID         ADV Router      Age         Seq#       Checksum Link count
10.0.40.1       10.0.40.1       1208        0x80000002 0x00B0F8 1
10.1.50.1       10.1.50.1       1205        0x80000002 0x00DB42 3

                Net Link States (Area 1)

Link ID         ADV Router      Age         Seq#       Checksum
10.1.0.1        10.0.40.1       1209        0x80000001 0x005C2D

                Summary Net Link States (Area 1)

Link ID         ADV Router      Age         Seq#       Checksum
10.0.0.0        10.0.40.1       1941        0x80000001 0x00BA27
10.0.1.0        10.0.40.1       1941        0x80000001 0x004B9F
10.0.20.1       10.0.40.1       1942        0x80000001 0x0015CA
10.0.40.1       10.0.40.1       1943        0x80000001 0x00D302
10.0.60.1       10.0.40.1       1943        0x80000001 0x005B5C
10.0.123.240    10.0.40.1       1943        0x80000001 0x00AAA1
10.0.123.244    10.0.40.1       1943        0x80000001 0x00641A
10.0.123.248    10.0.40.1       1943        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 56 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
```

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 56 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 2
R5#
```

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 10.2.0.1 255.255.255.0
R6(config-if)# no shut
R6(config)# router ospf 56
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 10.2.0.2 255.255.255.0
R8(config-if)# no shut
R8(config)#interface f0/0
R8(config-if)# ip addr 10.2.123.241 255.255.255.252
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 10.2.80.1 255.255.255.0
R8(config)# router ospf 56
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 。

```
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
O IA    10.1.1.0/24 [110/40] via 10.2.0.1, 00:01:21, FastEthernet0/1
O IA    10.0.0.0/24 [110/40] via 10.2.0.1, 00:01:21, FastEthernet0/1
O IA    10.1.0.0/24 [110/30] via 10.2.0.1, 00:01:21, FastEthernet0/1
O IA    10.0.1.0/24 [110/30] via 10.2.0.1, 00:01:21, FastEthernet0/1
O IA    10.0.20.1/32 [110/21] via 10.2.0.1, 00:01:22, FastEthernet0/1
O IA    10.0.40.1/32 [110/21] via 10.2.0.1, 00:01:22, FastEthernet0/1
O IA    10.0.60.1/32 [110/11] via 10.2.0.1, 00:01:22, FastEthernet0/1
O IA    10.1.50.1/32 [110/31] via 10.2.0.1, 00:01:22, FastEthernet0/1
C       10.2.80.0/24 is directly connected, Loopback0
O IA    10.0.123.240/30 [110/84] via 10.2.0.1, 00:01:22, FastEthernet0/1
C       10.2.123.240/30 is directly connected, FastEthernet0/0
O IA    10.0.123.244/30 [110/30] via 10.2.0.1, 00:01:25, FastEthernet0/1
O IA    10.0.123.248/29 [110/20] via 10.2.0.1, 00:01:25, FastEthernet0/1
```

PC4→PC1 的连通性：

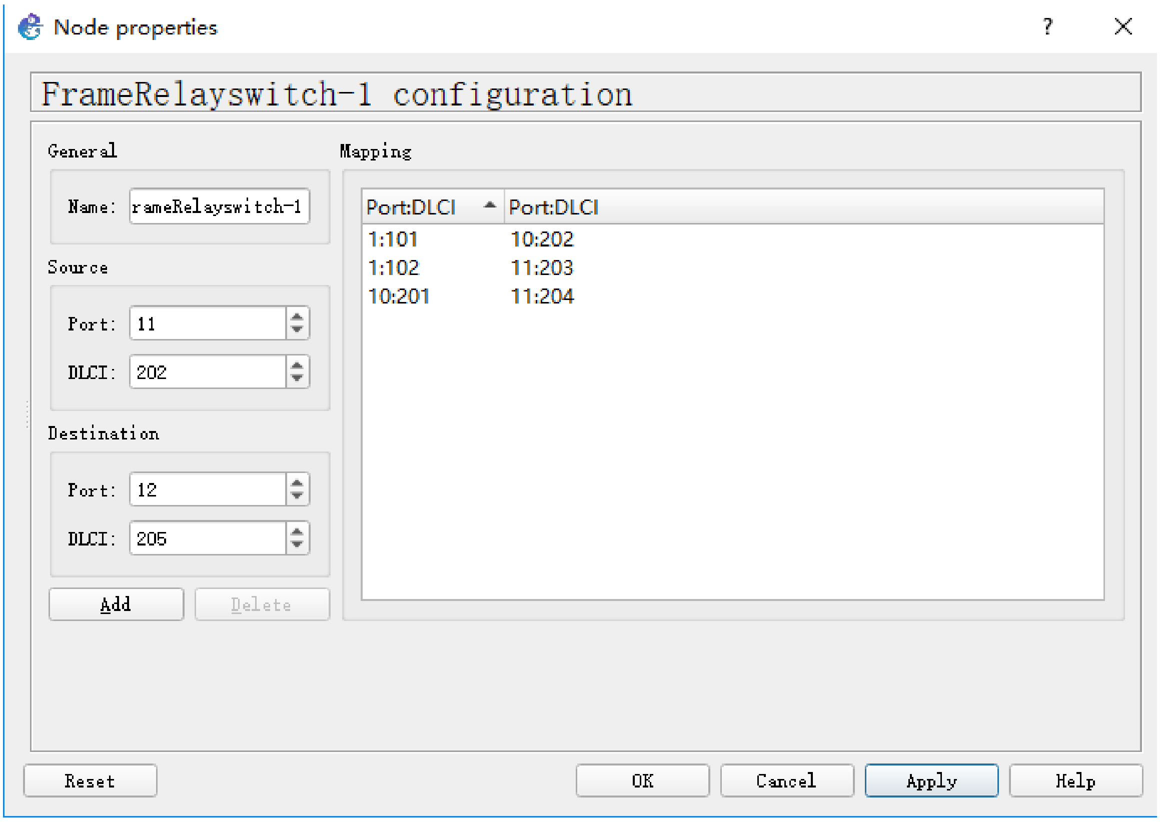
```
PC-4> ip 10.2.1.2 255.255.255.0 10.2.1.1
Checking for duplicate address...
PC1 : 10.2.1.2 255.255.255.0 gateway 10.2.1.1

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=69.260 ms
84 bytes from 10.0.0.2 icmp_seq=4 ttl=60 time=61.114 ms
84 bytes from 10.0.0.2 icmp_seq=5 ttl=60 time=77.866 ms
```

PC4→PC3 的连通性：

```
PC-4> 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=57.461 ms
84 bytes from 10.1.1.3 icmp_seq=4 ttl=60 time=63.574 ms
84 bytes from 10.1.1.3 icmp_seq=5 ttl=60 time=70.148 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 s2/0 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：

conf t
inter s0/0
encapsulation frame-relay
frame-relay lmi-type ANSI
no shutdown
exit
inter s0/0.1 multipoint
ip addr 10.1.2.5 255.255.255.0
frame-relay interface-dlci 101
exit
inter s0/0.2 multipoint
ip addr 10.1.2.6 255.255.255.0
frame-relay interface-dlci 102
exit

```
R5#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R5(config)#inter s0/0
R5(config-if)#encapsulation frame-relay
R5(config-if)#frame-relay lmi-type ANSI
R5(config-if)#no shutdown
R5(config-if)#exit
R5(config)#inter s0/0.1 multipoint
R5(config-subif)#ip addr 10.1.2.5 255.255.255.0
R5(config-subif)#frame-relay interface-dlci 101
R5(config-fr-dlci)#exit
R5(config-subif)#inter s0/0.2 multipoint
R5(config-subif)#ip addr 10.1.2.6 255.255.255.0
R5(config-subif)#frame-relay interface-dlci 102
R5(config-fr-dlci)#exit
*Mar  1 00:52:22.331: %LINK-3-UPDOWN: Interface Serial0/0, changed state to up
R5(config-fr-dlci)#exit
R5(config-subif)#exit
R5(config)#exit
R5#write
Building configuration...
```

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)# <u>ip addr 10.2.123.242 255.255.255.252</u>
R7(config-if)# <u>no shut</u>
R7(config)#interface s2/0
R7(config-if)# <u>ip addr 10.1.2.1 255.255.255.0</u> （IP 地址）
R7(config-if)# <u>encapsulation frame-relay</u> （封装协议）
R7(config-if)# <u>frame-relay lmi-type ANSI</u> （LMI）
R7(config-if)# <u>frame-relay interface-dlci 202</u> （DLCI）

R7(config-if)# no shut （激活）

R7(config)#interface loopback 0

R7(config-if)# ip addr 10.1.70.242 255.255.255.0

R7(config)# router ospf 56

R7(config-router)# network 10.1.0.0 0.0.255.255 area 1

R7(config-router)# network 10.2.0.0 0.0.255.255 area 2

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

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

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

```
Serial0/0.1 (up): ip 10.1.2.1 dlci 101(0x65,0x1850), dynamic,
              broadcast,, status defined, active
R5#
```

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 10.1.2.5

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 = 1/4/16 ms
R7#
```

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 s2/0

R9(config-if)# ip addr 10.1.2.3 255.255.255.0 （IP 地址）

R9(config-if)# encapsulation frame-relay （封装协议）

R9(config-if)# frame-relay lmi-type ANSI （LMI）

R9(config-if)# frame-relay interface-dlci 203 （DLCI）

R9(config-if)# no shut （激活）

R9(config)#interface loopback 0

R9(config-if)# ip addr 10.3.90.1 255.255.255.0

R9(config)# router ospf 56

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）：

```
[OK]
R9#show frame-relay map
Serial0/0 (up): ip 10.1.2.1 dlci 204(0xCC,0x30C0), dynamic,
              broadcast,, status defined, active
Serial0/0 (up): ip 10.1.2.6 dlci 203(0xCB,0x30B0), dynamic,
              broadcast,, status defined, active
R9#
```

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 10.1.2.5

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.1.2.5, timeout is 2 seconds:
.....
Success rate is 0 percent (0/5)
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 = 1/5/16 ms
R9#
```

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 10.1.2.1

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 = 1/4/12 ms
R9#
```

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 detail
 Neighbor 10.0.40.1, interface address 10.1.0.1
    In the area 1 via interface FastEthernet0/1
    Neighbor priority is 1, State is FULL, 6 state changes
    DR is 10.1.0.1 BDR is 10.1.0.2
    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 00:05:33
    Index 1/1, 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
R5#
```

在 R7 上查看邻居关系:

```
R7#show ip ospf neighbor detail
 Neighbor 10.2.80.1, interface address 10.2.123.241
    In the area 2 via interface FastEthernet0/0
    Neighbor priority is 1, State is FULL, 6 state changes
    DR is 10.2.123.241 BDR is 10.2.123.242
    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 00:00:33
    Neighbor is up for 00:05:43
    Index 1/1, 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
R7#
```

在 R9 上查看邻居关系:

```
R9#show ip ospf neighbor detail

R9#
```

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-mulitpoint），然后再次查看邻居关系：

R5 配置命令：

R5(config)#interface s2/0.1

R5(config-subif)# ip ospf network point-to-multipoint

R5(config)#interface s2/0.2

R5(config-subif)# ip ospf network point-to-multipoint

R7 配置命令：

R7(config)#interface s2/0

R7(config-if)# ip ospf network point-to-multipoint

R9 配置命令：

R9(config)#interface s2/0

R9(config-if)# ip ospf network point-to-multipoint

在 R5 上查看邻居关系:

```
R5#show ip ospf neighbor detail
 Neighbor 10.0.40.1, interface address 10.1.0.1
    In the area 1 via interface FastEthernet0/1
    Neighbor priority is 1, State is FULL, 6 state changes
    DR is 10.1.0.1 BDR is 10.1.0.2
    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 00:00:37
    Neighbor is up for 00:10:42
    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
 Neighbor 10.3.90.1, interface address 10.1.2.3
    In the area 1 via interface Serial0/0.2
    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 O-bit)
    LLS Options is 0x1 (LR)
    Dead timer due in 00:01:39
    Neighbor is up for 00:01:57
    Index 3/3, 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
 Neighbor 10.1.70.242, interface address 10.1.2.1
    In the area 1 via interface Serial0/0.1
    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 00:01:42
    Neighbor is up for 00:00:47
    Index 2/2, retransmission queue length 0, number of retransmission 1
    First 0x0(0)/0x0(0) Next 0x0(0)/0x0(0)
    Last retransmission scan length is 1, maximum is 1
    Last retransmission scan time is 0 msec, maximum is 0 msec
```

在 R7 上查看邻居关系:

```
R7#show ip ospf neighbor detail
 Neighbor 10.1.50.1, interface address 10.1.2.5
    In the area 1 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 O-bit)
    LLS Options is 0x1 (LR)
    Dead timer due in 00:01:32
    Neighbor is up for 00:01:32
    Index 2/3, 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
 Neighbor 10.3.90.1, interface address 10.1.2.3
    In the area 1 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 O-bit)
    LLS Options is 0x1 (LR)
    Dead timer due in 00:01:40
    Neighbor is up for 00:01:32
    Index 1/2, 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 10.2.80.1, interface address 10.2.123.241
    In the area 2 via interface FastEthernet0/0
    Neighbor priority is 1, State is FULL, 6 state changes
    DR is 10.2.123.241 BDR is 10.2.123.242
    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 00:00:35
    Neighbor is up for 00:01:57
    Index 1/1, 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
```

在 R9 上查看邻居关系:

```
R9#show ip ospf neighbor detail
 Neighbor 10.1.50.1, interface address 10.1.2.6
    In the area 1 via interface Serial0/0
    Neighbor priority is 1, State is FULL, 6 state changes
    DR is 0.0.0.0 BDR is 0.0.0.0
    Poll interval 120
    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 00:01:34
    Neighbor is up for 00:01:55
    Index 1/1, 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 10.1.70.242, interface address 10.1.2.1
    In the area 1 via interface Serial0/0
    Neighbor priority is 1, State is FULL, 6 state changes
    DR is 0.0.0.0 BDR is 0.0.0.0
    Poll interval 120
    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 00:01:58
    Neighbor is up for 00:01:54
    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
```

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。

```
                Summary Net Link States (Area 1)

Link ID         ADV Router      Age         Seq#       Checksum
10.0.0.0        10.0.40.1       1165        0x80000001 0x00BA27
10.0.1.0        10.0.40.1       1165        0x80000001 0x004B9F
10.0.20.1       10.0.40.1       1165        0x80000001 0x0015CA
10.0.40.1       10.0.40.1       1205        0x80000001 0x00D302
10.0.60.1       10.0.40.1       1157        0x80000001 0x005B5C
10.0.123.240    10.0.40.1       1168        0x80000001 0x00AAA1
10.0.123.244    10.0.40.1       1168        0x80000001 0x00641A
10.0.123.248    10.0.40.1       1208        0x80000001 0x00BFC8
10.2.0.0        10.0.40.1       1159        0x80000001 0x003EAB
10.2.1.0        10.0.40.1       1159        0x80000001 0x003DAA
10.2.80.1       10.0.40.1       1160        0x80000001 0x00CACC
10.2.123.240    10.0.40.1       1160        0x80000001 0x00D89D
R5#
```

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，。

```
                 Summary Net Link States (Area 2)

Link ID         ADV Router      Age         Seq#       Checksum
10.0.0.0        10.0.60.1       1280        0x80000001 0x002E9F
10.0.1.0        10.0.60.1       1280        0x80000001 0x00BE18
10.0.20.1       10.0.60.1       1280        0x80000001 0x008843
10.0.40.1       10.0.60.1       1270        0x80000001 0x00AB0C
10.0.60.1       10.0.60.1       1319        0x80000001 0x006A43
10.0.123.240    10.0.60.1       1282        0x80000001 0x001E1A
10.0.123.244    10.0.60.1       1282        0x80000001 0x00D792
10.0.123.248    10.0.60.1       1321        0x80000001 0x003341
10.1.0.0        10.0.60.1       1272        0x80000001 0x00BD19
10.1.1.0        10.0.60.1       862         0x80000001 0x0017B4
10.1.2.1        10.0.60.1       254         0x80000001 0x002073
10.1.2.5        10.0.60.1       349         0x80000001 0x00755A
10.1.2.6        10.0.60.1       349         0x80000001 0x006B63
10.1.50.1       10.0.60.1       863         0x80000001 0x00950D
10.1.70.242     10.0.60.1       255         0x80000001 0x00C794
R8#
```

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。

```
                 Summary Net Link States (Area 1)

Link ID         ADV Router      Age         Seq#       Checksum
10.0.0.0        10.0.40.1       1341        0x80000001 0x00BA27
10.0.1.0        10.0.40.1       1341        0x80000001 0x004B9F
10.0.20.1       10.0.40.1       1341        0x80000001 0x0015CA
10.0.40.1       10.0.40.1       1381        0x80000001 0x00D302
10.0.60.1       10.0.40.1       1333        0x80000001 0x005B5C
10.0.123.240    10.0.40.1       1344        0x80000001 0x00AAA1
10.0.123.244    10.0.40.1       1344        0x80000001 0x00641A
10.0.123.248    10.0.40.1       1384        0x80000001 0x00BFC8
10.2.0.0        10.0.40.1       1334        0x80000001 0x003EAB
10.2.1.0        10.0.40.1       1334        0x80000001 0x003DAA
10.2.80.1       10.0.40.1       1334        0x80000001 0x00CACC
10.2.123.240    10.0.40.1       1335        0x80000001 0x00D89D
```

```
                 Summary Net Link States (Area 2)

Link ID         ADV Router      Age         Seq#       Checksum
10.0.0.0        10.0.60.1       1345        0x80000001 0x002E9F
10.0.1.0        10.0.60.1       1346        0x80000001 0x00BE18
10.0.20.1       10.0.60.1       1347        0x80000001 0x008843
10.0.40.1       10.0.60.1       1337        0x80000001 0x00AB0C
10.0.60.1       10.0.60.1       1386        0x80000001 0x006A43
10.0.123.240    10.0.60.1       1347        0x80000001 0x001E1A
10.0.123.244    10.0.60.1       1348        0x80000001 0x00D792
10.0.123.248    10.0.60.1       1387        0x80000001 0x003341
10.1.0.0        10.0.60.1       1338        0x80000001 0x00BD19
10.1.1.0        10.0.60.1       928         0x80000001 0x0017B4
10.1.2.1        10.0.60.1       320         0x80000001 0x002073
10.1.2.5        10.0.60.1       414         0x80000001 0x00755A
10.1.2.6        10.0.60.1       414         0x80000001 0x006B63
10.1.50.1       10.0.60.1       928         0x80000001 0x00950D
10.1.70.242     10.0.60.1       321         0x80000001 0x00C794
```

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 的下一跳 IP 地址是 10.2.0.1 ，是路由器 R6 。

```
R8#show ip route 10.1.1.0
Routing entry for 10.1.1.0/24
  Known via "ospf 56", distance 110, metric 40, type inter area
  Last update from 10.2.0.1 on FastEthernet0/1, 00:07:12 ago
  Routing Descriptor Blocks:
  * 10.2.0.1, from 10.0.60.1, 00:07:12 ago, via FastEthernet0/1
      Route metric is 40, traffic share count is 1

R8#
```

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。

```
Gateway of last resort is not set

     10.0.0.0/8 is variably subnetted, 5 subnets, 3 masks
C       10.2.0.0/24 is directly connected, FastEthernet0/1
C       10.2.1.0/24 is directly connected, FastEthernet1/0
O IA    10.0.60.1/32 [110/11] via 10.2.0.1, 00:09:53, FastEthernet0/1
C       10.2.80.0/24 is directly connected, Loopback0
C       10.2.123.240/30 is directly connected, FastEthernet0/0
R8#
```

看看 R7 有没有 PC3 的路由信息：观察得知，前往子网 10.1.1.0/24 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 56", distance 110, metric 74, type intra area
  Last update from 10.1.2.5 on Serial0/0, 00:11:15 ago
  Routing Descriptor Blocks:
  * 10.1.2.5, from 10.1.50.1, 00:11:15 ago, via Serial0/0
      Route metric is 74, traffic share count is 1
```

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。

```
Gateway of last resort is not set

     10.0.0.0/8 is variably subnetted, 19 subnets, 4 masks
C       10.2.0.0/24 is directly connected, FastEthernet0/1
O IA    10.1.2.1/32 [110/94] via 10.2.0.1, 00:00:06, FastEthernet0/1
C       10.2.1.0/24 is directly connected, FastEthernet1/0
O IA    10.1.1.0/24 [110/40] via 10.2.0.1, 00:00:06, FastEthernet0/1
O IA    10.0.0.0/24 [110/40] via 10.2.0.1, 00:00:06, FastEthernet0/1
O IA    10.1.0.0/24 [110/30] via 10.2.0.1, 00:00:06, FastEthernet0/1
O IA    10.0.1.0/24 [110/30] via 10.2.0.1, 00:00:07, FastEthernet0/1
O IA    10.1.2.5/32 [110/30] via 10.2.0.1, 00:00:07, FastEthernet0/1
O IA    10.1.2.6/32 [110/30] via 10.2.0.1, 00:00:07, FastEthernet0/1
O IA    10.0.20.1/32 [110/21] via 10.2.0.1, 00:00:07, FastEthernet0/1
O IA    10.0.40.1/32 [110/21] via 10.2.0.1, 00:00:07, FastEthernet0/1
O IA    10.0.60.1/32 [110/11] via 10.2.0.1, 00:12:51, FastEthernet0/1
O IA    10.1.50.1/32 [110/31] via 10.2.0.1, 00:00:07, FastEthernet0/1
C       10.2.80.0/24 is directly connected, Loopback0
O IA    10.0.123.240/30 [110/84] via 10.2.0.1, 00:00:07, FastEthernet0/1
C       10.2.123.240/30 is directly connected, FastEthernet0/0
O IA    10.0.123.244/30 [110/30] via 10.2.0.1, 00:00:07, FastEthernet0/1
O IA    10.0.123.248/29 [110/20] via 10.2.0.1, 00:00:19, FastEthernet0/1
O IA    10.1.70.242/32 [110/95] via 10.2.0.1, 00:00:10, FastEthernet0/1
R8#
R8#
```

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：

```
R8(config)#interface f0/1
R8(config-if)#  ip addr 10.3.0.2 255.255.255.0
R8(config-if)#  no shut
R8(config)#interface f0/0
R8(config-if)#  ip addr 10.3.1.1 255.255.255.0
R8(config-if)#  no shut
R8(config)#interface loopback 0
R8(config-if)#  ip addr 10.3.100.1 255.255.255.0
R8(config)#  router ospf 56
R8(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 56)

                Router Link States (Area 3)

Link ID         ADV Router      Age         Seq#       Checksum Link count
10.3.90.1       10.3.90.1       58          0x80000003 0x00E4DC 2
10.3.100.1      10.3.100.1      52          0x80000002 0x0098E2 3

                Net Link States (Area 3)

Link ID         ADV Router      Age         Seq#       Checksum
10.3.0.1        10.3.90.1       58          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, 4 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
O       10.3.90.1/32 [110/11] via 10.3.0.1, 00:01:48, FastEthernet0/1
C       10.3.100.0/24 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 56

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

R9 配置命令：

R9(config)# router ospf 56

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 f0/1 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_VL1 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 00:00:05
    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__s0/0__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 00:00:00
    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_VL1___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
10.0.20.1         1   FULL/DROTHER    00:00:30    10.0.123.249    FastEthernet0/0
10.0.30.1         1   FULL/DROTHER    00:00:30    10.0.123.250    FastEthernet0/0
10.0.60.1         1   FULL/DR         00:00:30    10.0.123.252    FastEthernet0/0
10.3.90.1         0   FULL/  -            -       10.1.2.3        OSPF_VL1
10.1.50.1         1   FULL/BDR        00:00:31    10.1.0.2        FastEthernet0/1
R4#
```

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/  -        00:01:57    10.1.2.6        Serial0/0
10.3.100.1        1   FULL/DR         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：

```
Gateway of last resort is not set

     10.0.0.0/8 is variably subnetted, 24 subnets, 4 masks
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, 00:04:31, FastEthernet0/1
O IA    10.1.2.1/32 [110/138] via 10.3.0.1, 00:04:41, 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, 00:04:31, FastEthernet0/1
O IA    10.1.2.3/32 [110/10] via 10.3.0.1, 00:04:41, FastEthernet0/1
O IA    10.1.1.0/24 [110/84] via 10.3.0.1, 00:04:42, FastEthernet0/1     PC3
O IA    10.0.0.0/24 [110/114] via 10.3.0.1, 00:04:33, FastEthernet0/1    PC1
O IA    10.1.0.0/24 [110/84] via 10.3.0.1, 00:04:42, FastEthernet0/1
O IA    10.0.1.0/24 [110/104] via 10.3.0.1, 00:04:33, FastEthernet0/1    PC2
O IA    10.1.2.5/32 [110/74] via 10.3.0.1, 00:04:42, FastEthernet0/1
O IA    10.1.2.6/32 [110/74] via 10.3.0.1, 00:04:42, FastEthernet0/1
O IA    10.0.20.1/32 [110/95] via 10.3.0.1, 00:04:33, FastEthernet0/1
O IA    10.0.40.1/32 [110/85] via 10.3.0.1, 00:04:33, FastEthernet0/1
O IA    10.0.60.1/32 [110/95] via 10.3.0.1, 00:04:33, FastEthernet0/1
O IA    10.1.50.1/32 [110/75] via 10.3.0.1, 00:04:43, FastEthernet0/1
O       10.3.90.1/32 [110/11] via 10.3.0.1, 00:04:43, FastEthernet0/1
O IA    10.2.80.1/32 [110/105] via 10.3.0.1, 00:04:33, FastEthernet0/1
C       10.3.100.0/24 is directly connected, Loopback0
O IA    10.0.123.240/30 [110/158] via 10.3.0.1, 00:04:34, FastEthernet0/1
O IA    10.2.123.240/30 [110/114] via 10.3.0.1, 00:04:34, FastEthernet0/1
O IA    10.0.123.244/30 [110/104] via 10.3.0.1, 00:04:34, FastEthernet0/1
O IA    10.0.123.248/29 [110/94] via 10.3.0.1, 00:04:34, FastEthernet0/1
O IA    10.1.70.242/32 [110/139] via 10.3.0.1, 00:04:44, FastEthernet0/1
R10#
```

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。

```
                Summary Net Link States (Area 3)

Link ID         ADV Router      Age         Seq#       Checksum
10.0.0.0        10.3.90.1       397         0x80000001 0x002A38
10.0.1.0        10.3.90.1       397         0x80000001 0x00BAB0
10.0.20.1       10.3.90.1       397         0x80000001 0x0084DB
10.0.40.1       10.3.90.1       397         0x80000001 0x004313
10.0.60.1       10.3.90.1       397         0x80000001 0x00CA6D
10.0.123.240    10.3.90.1       397         0x80000001 0x001AB2
10.0.123.244    10.3.90.1       397         0x80000001 0x00D32B
10.0.123.248    10.3.90.1       400         0x80000001 0x002FD9
10.1.0.0        10.3.90.1       418         0x80000001 0x00F08E
10.1.1.0        10.3.90.1       418         0x80000001 0x00E598
10.1.2.1        10.3.90.1       418         0x80000001 0x00EE57
10.1.2.3        10.3.90.1       418         0x80000001 0x00D5EE
10.1.2.5        10.3.90.1       418         0x80000001 0x00443E
10.1.2.6        10.3.90.1       418         0x80000001 0x003A47
10.1.50.1       10.3.90.1       418         0x80000001 0x0064F0
10.1.70.242     10.3.90.1       418         0x80000001 0x009678
10.2.0.0        10.3.90.1       403         0x80000001 0x00ADBC
10.2.1.0        10.3.90.1       403         0x80000001 0x00ACBB
10.2.80.1       10.3.90.1       403         0x80000001 0x003ADD
10.2.123.240    10.3.90.1       403         0x80000001 0x0048AE
```

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。

```
Gateway of last resort is not set

     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, 00:00:21, FastEthernet0/1
O IA    10.2.0.0/24 [110/94] via 10.1.2.6, 00:00:21, Serial0/0
O       10.1.2.1/32 [110/128] via 10.1.2.6, 00:00:21, 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, 00:00:21, Serial0/0
C       10.1.2.0/24 is directly connected, Serial0/0
O       10.1.1.0/24 [110/74] via 10.1.2.6, 00:00:21, Serial0/0
O       10.0.0.0/24 [110/104] via 10.1.2.6, 00:00:22, Serial0/0
O       10.0.0.0/16 is a summary, 00:00:22, Null0
O       10.1.0.0/24 [110/74] via 10.1.2.6, 00:00:22, Serial0/0
O       10.0.1.0/24 [110/94] via 10.1.2.6, 00:00:22, Serial0/0
O       10.1.2.5/32 [110/64] via 10.1.2.6, 00:00:22, Serial0/0
O       10.1.2.6/32 [110/64] via 10.1.2.6, 00:00:28, Serial0/0
O       10.0.20.1/32 [110/85] via 10.1.2.6, 00:00:28, Serial0/0
O       10.0.40.1/32 [110/75] via 10.1.2.6, 00:00:28, Serial0/0
O       10.0.60.1/32 [110/85] via 10.1.2.6, 00:00:28, Serial0/0
O       10.1.50.1/32 [110/65] via 10.1.2.6, 00:00:28, Serial0/0
C       10.3.90.0/24 is directly connected, Loopback0
O IA    10.2.80.1/32 [110/95] via 10.1.2.6, 00:00:29, Serial0/0
O       10.3.100.1/32 [110/11] via 10.3.0.2, 00:00:29, FastEthernet0/1
O       10.0.123.240/30 [110/148] via 10.1.2.6, 00:00:29, Serial0/0
O IA    10.2.123.240/30 [110/104] via 10.1.2.6, 00:00:29, Serial0/0
O       10.0.123.244/30 [110/94] via 10.1.2.6, 00:00:29, Serial0/0
O       10.0.123.248/29 [110/84] via 10.1.2.6, 00:00:29, Serial0/0
O       10.1.70.242/32 [110/129] via 10.1.2.6, 00:00:29, 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<u> 10.3.0.1   </u>，是路由器<u>   R9   </u>的接口。

```
Gateway of last resort is not set

     10.0.0.0/8 is variably subnetted, 17 subnets, 4 masks
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, 00:18:03, FastEthernet0/1
O IA    10.1.2.1/32 [110/138] via 10.3.0.1, 00:18:13, 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, 00:18:03, FastEthernet0/1
O IA    10.1.2.3/32 [110/10] via 10.3.0.1, 00:18:13, FastEthernet0/1
O IA    10.1.1.0/24 [110/84] via 10.3.0.1, 00:18:14, FastEthernet0/1
O IA    10.0.0.0/16 [110/85] via 10.3.0.1, 00:00:27, FastEthernet0/1
O IA    10.1.0.0/24 [110/84] via 10.3.0.1, 00:18:14, FastEthernet0/1
O IA    10.1.2.5/32 [110/74] via 10.3.0.1, 00:18:14, FastEthernet0/1
O IA    10.1.2.6/32 [110/74] via 10.3.0.1, 00:18:14, FastEthernet0/1
O IA    10.1.50.1/32 [110/75] via 10.3.0.1, 00:18:14, FastEthernet0/1
O       10.3.90.1/32 [110/11] via 10.3.0.1, 00:19:30, FastEthernet0/1
O IA    10.2.80.1/32 [110/105] via 10.3.0.1, 00:19:21, FastEthernet0/1
C       10.3.100.0/24 is directly connected, Loopback0
O IA    10.2.123.240/30 [110/114] via 10.3.0.1, 00:19:21, FastEthernet0/1
O IA    10.1.70.242/32 [110/139] via 10.3.0.1, 00:19:31, FastEthernet0/1
R10#
```

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？

  答：不一定要相同。一个路由器上可以配置多个进程号。

- 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？

  答：前者会选取串口作为 RouterID，后者会选取回环接口作为 RouterID。

- 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？

  答：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？

  答：不是子网掩码，而是反掩码。为了方便路由器进行匹配。

- 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？

  答：不是。虚链路能够在两台 ABR 之间，穿过一个非骨干区域建立一条逻辑上的连接通道（点对点连接）。

- 为什么要在区域边界路由器上进行路由合并？

  答：为了方便路由器进行路由寻找。

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：

1. 对虚链路实现的原理还是不太理解。

2. 不知道为什么 GNS3 好多时候出问题了往往重启就解决了。

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：

1. 按照教程一步一步做，当使用 PC-4 去测试 PC-1 时，发现连不通，最后发现是没有给 PC4 配置 IP 地址和网关所导致的，配置一下即可。

```
PC-4>
PC-4> ping 10.0.0.2
host (10.0.0.2) not reachable
```

2. 下午做了一半多，原来能够 PING 通 PC-4 和 PC-1 的，到了晚上突然怎么都 PING 不通，甚至连隔壁的路由器都 PING 不通，通过 SHOW RUN 查看路由器配置没有问题，果断重启后又有用了。

你对本实验安排有哪些更好的建议呢？欢迎献计献策：

1. 感觉实验的量有点大了，可以适当缩减一些量（主要是重复操作过多），而且路由器和 PC 机过多，做到后面往往整个人都有些糊涂了。

2. 可以再给出一些原理性提示，如某个步骤执行的作用是什么，为什么要执行该步骤。