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

- 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

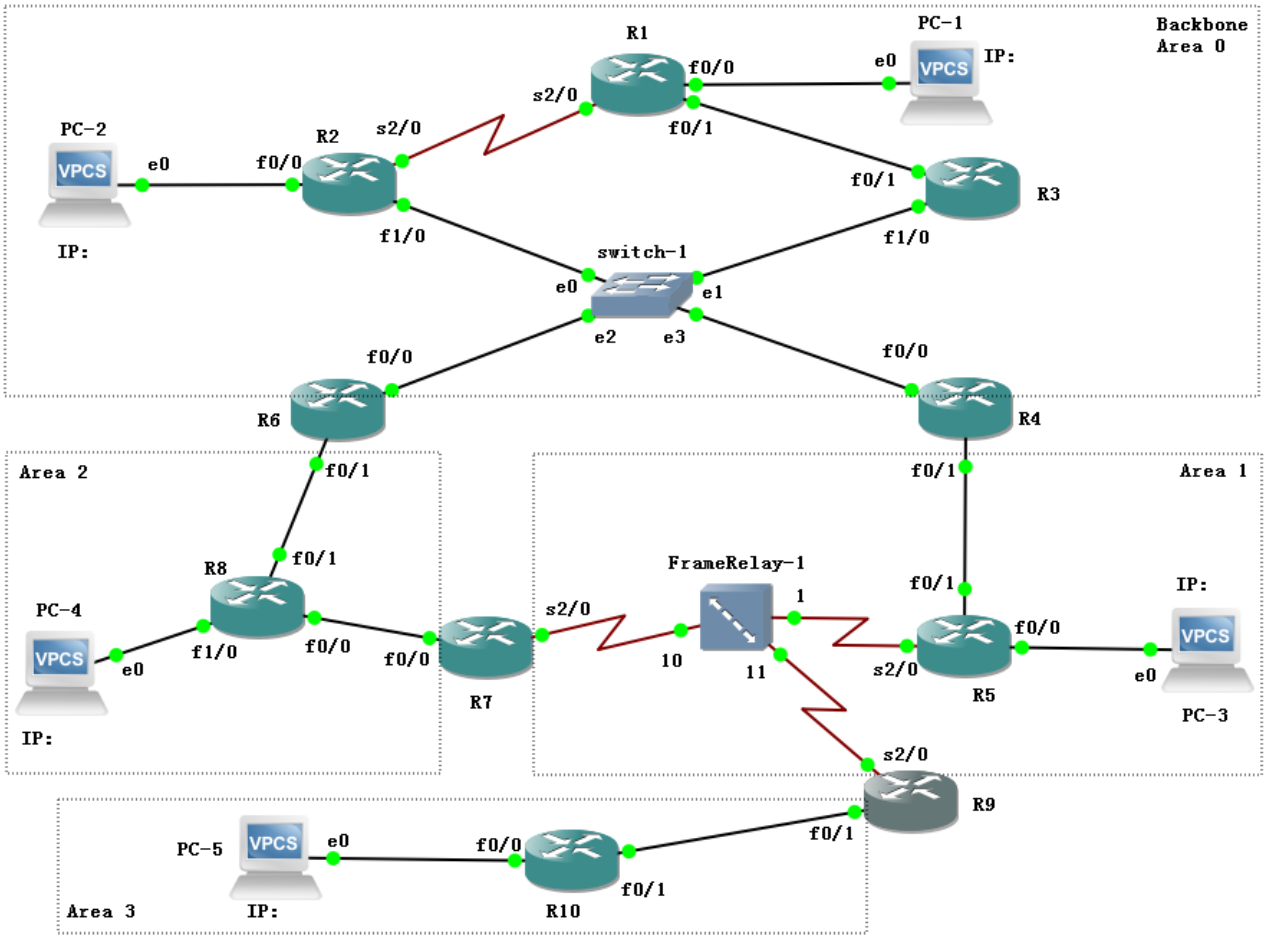
址部分为 30 位，每个子网刚好有 2 个可用地址（去掉 1 个主机地址部分全 0 的和 1 个主机地址部分全 1 的），可以按如下方式进行分配：

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：

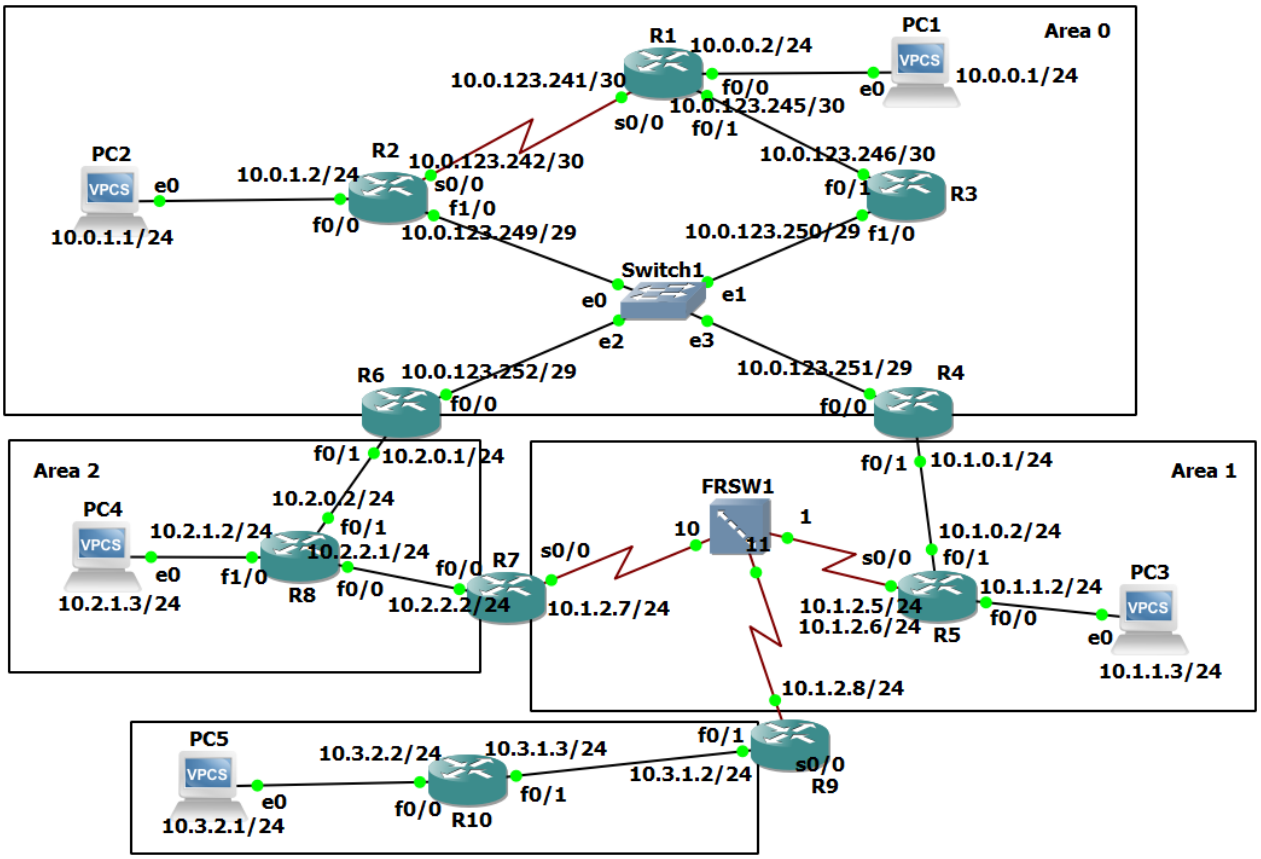
  ```
  Router(config-router)# area <area-id> range <ip_net> <mask>
  ```

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）：

```
R1#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R1(config)#interface f0/0
R1(config-if)#ip address 10.0.0.2 255.255.255.0
R1(config-if)#no shutdown
R1(config-if)#exit
R1(config)#interface f0/1
R1(config-if)#ip address 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 address 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
R1(config)#exit
```

使用命令“show ip interface brief”查看配置

```
R1#show ip interface brief
Interface                  IP-Address      OK? Method Status                Protocol
FastEthernet0/0            10.0.0.2        YES manual up                    up
Serial0/0                  10.0.123.241    YES manual up                    up
FastEthernet0/1            10.0.123.245    YES manual up                    up
```

R2 配置命令：

```
R2#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R2(config)#interface f0/0
R2(config-if)#ip address 10.0.1.2 255.255.255.0
R2(config-if)#no shutdown
R2(config-if)#exit
R2(config)#
*Mar  1 07:32:41.106: %LINK-3-UPDOWN: Interface FastEthernet0/0, changed state to up
*Mar  1 07:32:42.106: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet0/0, chang
ed state to up
R2(config)#interface f1/0
R2(config-if)#ip address 10.0.123.249 255.255.255.248
R2(config-if)#no shutdown
R2(config-if)#exit
R2(config)#
*Mar  1 07:38:19.714: %LINK-3-UPDOWN: Interface FastEthernet1/0, changed state to up
*Mar  1 07:38:20.714: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet1/0, chang
ed state to up
R2(config)#interface s0/0
R2(config-if)#ip address 10.0.123.242 255.255.255.252
R2(config-if)#encapsulation hdlc
R2(config-if)#no shutdown
R2(config-if)#exit
```

R3 配置命令：

```
R3#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R3(config)#interface f0/1
R3(config-if)#ip address 10.0.123.246 255.255.255.252
R3(config-if)#no shutdown
R3(config-if)#exit
R3(config)#
*Mar  1 07:40:55.030: %LINK-3-UPDOWN: Interface FastEthernet0/1, changed state to up
*Mar  1 07:40:56.030: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet0/1, chang
ed state to up
R3(config)#interface f1/0
R3(config-if)#ip address 10.0.123.250 255.255.255.248
R3(config-if)#no shutdown
R3(config-if)#exit
R3(config)#
*Mar  1 07:42:45.638: %LINK-3-UPDOWN: Interface FastEthernet1/0, changed state to up
*Mar  1 07:42:46.638: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet1/0, chang
ed state to up
R3(config)#exit
```

Ping 测试结果截图

PC1→R1:

```
PC1> ping 10.0.0.2

84 bytes from 10.0.0.2 icmp_seq=1 ttl=255 time=30.169 ms
84 bytes from 10.0.0.2 icmp_seq=2 ttl=255 time=4.010 ms
84 bytes from 10.0.0.2 icmp_seq=3 ttl=255 time=15.811 ms
84 bytes from 10.0.0.2 icmp_seq=4 ttl=255 time=16.199 ms
84 bytes from 10.0.0.2 icmp_seq=5 ttl=255 time=16.959 ms
```

PC2→R2:

```
PC2> ping 10.0.1.2

84 bytes from 10.0.1.2 icmp_seq=1 ttl=255 time=19.919 ms
84 bytes from 10.0.1.2 icmp_seq=2 ttl=255 time=4.822 ms
84 bytes from 10.0.1.2 icmp_seq=3 ttl=255 time=14.021 ms
84 bytes from 10.0.1.2 icmp_seq=4 ttl=255 time=10.484 ms
84 bytes from 10.0.1.2 icmp_seq=5 ttl=255 time=4.261 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#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R1(config)#router rip
R1(config-router)#network 10.0.0.0
R1(config-router)#network 10.0.123.240
R1(config-router)#network 10.0.123.244
R1(config-router)#version 2
R1(config-router)#exit
```

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)#network 10.0.1.0
R2(config-router)#network 10.0.123.240
R2(config-router)#network 10.0.123.248
R2(config-router)#version 2
R2(config-router)#exit
```

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)#network 10.0.123.244
R3(config-router)#network 10.0.123.248
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）：下一跳是 R2 路由器

```
R1#show ip route
Codes: C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route

Gateway of last resort is not set

     10.0.0.0/8 is variably subnetted, 5 subnets, 3 masks
C       10.0.0.0/24 is directly connected, FastEthernet0/0
R       10.0.1.0/24 [120/1] via 10.0.123.242, 00:00:00, 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, 00:00:11, 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）：下一跳是 R1 路由器

```
R2#show ip route
Codes: C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route

Gateway of last resort is not set

     10.0.0.0/8 is variably subnetted, 5 subnets, 3 masks
R       10.0.0.0/24 [120/1] via 10.0.123.241, 00:00:12, 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, 00:00:20, FastEthernet1/0
                        [120/1] via 10.0.123.241, 00:00:12, Serial0/0
C       10.0.123.248/29 is directly connected, FastEthernet1/0
```

R3 路由表：

```
R3#show ip route
Codes: C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route

Gateway of last resort is not set

     10.0.0.0/8 is variably subnetted, 5 subnets, 3 masks
R       10.0.0.0/24 [120/1] via 10.0.123.245, 00:00:05, FastEthernet0/1
R       10.0.1.0/24 [120/1] via 10.0.123.249, 00:00:23, FastEthernet1/0
R       10.0.123.240/30 [120/1] via 10.0.123.249, 00:00:23, FastEthernet1/0
                        [120/1] via 10.0.123.245, 00:00:05, FastEthernet0/1
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____、____R2____）

```
PC1> trace 10.0.1.2
trace to 10.0.1.2, 8 hops max, press Ctrl+C to stop
 1   10.0.0.2   9.832 ms  10.034 ms  10.251 ms
 2   *10.0.123.242   9.220 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：

```
R1#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R1(config)#router ospf 77
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#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R2(config)#interface loopback 0
R2(config-if)#
*Mar  1 09:37:52.397: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback0, changed st
ate to upi
R2(config-if)#ip address 10.0.20.1 255.255.255.252
R2(config-if)#exit
R2(config)#router ospf 77
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#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R3(config)#router ospf 77
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 77)

                Router Link States (Area 0)

Link ID         ADV Router      Age         Seq#       Checksum Link count
10.0.20.1       10.0.20.1       34          0x80000002 0x00E5B3 5
10.0.30.1       10.0.30.1       34          0x80000001 0x003F90 2
10.0.123.245    10.0.123.245    33          0x80000003 0x001756 4

                Net Link States (Area 0)

Link ID         ADV Router      Age         Seq#       Checksum
10.0.123.245    10.0.123.245    33          0x80000001 0x00DFC1
10.0.123.249    10.0.20.1       34          0x80000001 0x00FC5D
```

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#show ip ospf database

            OSPF Router with ID (10.0.20.1) (Process ID 77)

                Router Link States (Area 0)

Link ID         ADV Router      Age         Seq#       Checksum Link count
10.0.20.1       10.0.20.1       1731        0x8000000A 0x00D5BB 5
10.0.30.1       10.0.30.1       1584        0x80000009 0x002F98 2
10.0.123.245    10.0.123.245    1315        0x8000000C 0x00055F 4

                Net Link States (Area 0)

Link ID         ADV Router      Age         Seq#       Checksum
10.0.123.245    10.0.123.245    1820        0x80000009 0x00CFC9
10.0.123.249    10.0.20.1       1731        0x80000009 0x00EC65
```

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 77)

                Router Link States (Area 0)

Link ID         ADV Router      Age         Seq#       Checksum Link count
10.0.20.1       10.0.20.1       1766        0x80000024 0x00A1D5 5
10.0.30.1       10.0.30.1       1940        0x80000023 0x00FAB2 2
10.0.123.245    10.0.123.245    1890        0x80000026 0x00D079 4

                Net Link States (Area 0)

Link ID         ADV Router      Age         Seq#       Checksum
10.0.123.245    10.0.123.245    143         0x80000024 0x0099E4
10.0.123.249    10.0.20.1       1765        0x80000023 0x00B87F
```

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 77, 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 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 ）

```
FastEthernet0/1 is up, line protocol is up
  Internet Address 10.0.123.245/30, Area 0
  Process ID 77, 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 00:00:08
  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 1
  Last flood scan time is 0 msec, maximum is 4 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:（f0/0 连接的网络类型为__BROADCAST__，Cost=10，DR 的 Router ID 是 10.0.123.245，接口 IP 是 10.0.0.2）

```
FastEthernet0/0 is up, line protocol is up
  Internet Address 10.0.0.2/24, Area 0
  Process ID 77, 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 10.0.0.2
  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 00:00:05
  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）

```
R1#SHOW IP ROUTE
Codes: C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route

Gateway of last resort is not set

     10.0.0.0/8 is variably subnetted, 7 subnets, 4 masks
C       10.0.0.0/24 is directly connected, FastEthernet0/0
O       10.0.1.0/24 [110/21] via 10.0.123.246, 19:42:39, FastEthernet0/1
R       10.0.20.0/30 [120/1] via 10.0.123.242, 00:00:05, Serial0/0
O       10.0.20.1/32 [110/12] via 10.0.123.246, 19:42:39, 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, 19:42:40, 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 ）

```
R2#show ip route
Codes: C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route

Gateway of last resort is not set

     10.0.0.0/8 is variably subnetted, 6 subnets, 3 masks
O       10.0.0.0/24 [110/21] via 10.0.123.250, 19:45:01, 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, 19:45:01, FastEthernet1/0
C       10.0.123.248/29 is directly connected, FastEthernet1/0
```

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, 19:47:05, FastEthernet0/1
O       10.0.1.0/24 [110/11] via 10.0.123.249, 19:47:05, FastEthernet1/0
R       10.0.20.0/30 [120/1] via 10.0.123.249, 00:00:01, FastEthernet1/0
O       10.0.20.1/32 [110/2] via 10.0.123.249, 19:47:05, FastEthernet1/0
O       10.0.123.240/30 [110/65] via 10.0.123.249, 19:47:05, 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 ）

```
PC1> trace 10.0.1.1
trace to 10.0.1.1, 8 hops max, press Ctrl+C to stop
 1   10.0.0.2   7.051 ms  9.684 ms  10.252 ms
 2   10.0.123.246   20.022 ms  20.776 ms  31.071 ms
 3   10.0.123.249   41.424 ms  40.581 ms  30.029 ms
 4   *10.0.1.1   60.347 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：

```
R1#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R1(config)#interface f0/1
R1(config-if)#shutdown
R1(config-if)#
*Mar  2 13:48:50.114: %OSPF-5-ADJCHG: Process 77, Nbr 10.0.30.1 on FastEthernet0/1 from FUL
L to DOWN, Neighbor Down: Interface down or detached
```

```
R1#show ip route
Codes: C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route

Gateway of last resort is not set

     10.0.0.0/8 is variably subnetted, 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, 00:00:14, Serial0/0
R       10.0.20.0/30 [120/1] via 10.0.123.242, 00:00:28, Serial0/0
O       10.0.20.1/32 [110/65] via 10.0.123.242, 00:00:14, 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, 00:00:14, 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 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 77)

                Router Link States (Area 0)

Link ID         ADV Router      Age         Seq#       Checksum Link count
10.0.20.1       10.0.20.1       68          0x80000026 0x001564 5
10.0.30.1       10.0.30.1       378         0x80000025 0x00A288 2
10.0.123.241    10.0.123.241    61          0x80000002 0x004442 3
10.0.123.245    10.0.123.245    415         0x80000028 0x00B7A0 3

                Net Link States (Area 0)

Link ID         ADV Router      Age         Seq#       Checksum
10.0.123.249    10.0.20.1       1624        0x80000024 0x00B680
```

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 state INIT 、state_2WAY 、state_EXSTART 、 state_EXCHANGE 、 state_FULL ）

```
R1#debug ip ospf events
OSPF events debugging is on
```

```
R1(config)#interface f0/1
R1(config-if)#no shutdown
```

```
R1#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R1(config)#
*Mar  1 00:07:35.299: OSPF: Rcv hello from 10.0.20.1 area 0 from Serial0/0 10.0.123.242
*Mar  1 00:07:35.303: OSPF: End of hello processing
R1(config)#
*Mar  1 00:07:36.675: OSPF: Rcv LS UPD from 10.0.20.1 on Serial0/0 length 112 LSA count 1
*Mar  1 00:07:36.695: OSPF: Rcv LS UPD from 10.0.20.1 on Serial0/0 length 60 LSA count 1
*Mar  1 00:07:37.227: OSPF: Send hello to 224.0.0.5 area 0 on Serial0/0 from 10.0.123.241
*Mar  1 00:07:37.231: OSPF: Send hello to 224.0.0.5 area 0 on FastEthernet0/0 from 10.0.0.
2
R1(config)#interface f0/
*Mar  1 00:07:45.327: OSPF: Rcv hello from 10.0.20.1 area 0 from Serial0/0 10.0.123.242
*Mar  1 00:07:45.327: OSPF: End of hello processing
R1(config)#interface f0/1
*Mar  1 00:07:47.227: OSPF: Send hello to 224.0.0.5 area 0 on Serial0/0 from 10.0.123.241
*Mar  1 00:07:47.231: OSPF: Send hello to 224.0.0.5 area 0 on FastEthernet0/0 from 10.0.0.
2
R1(config)#interface f0/1
R1(config-if)#no shutdown
R1(config-if)#
*Mar  1 00:07:55.307: OSPF: Rcv hello from 10.0.20.1 area 0 from Serial0/0 10.0.123.242
*Mar  1 00:07:55.307: OSPF: End of hello processing
*Mar  1 00:07:55.879: OSPF: Interface FastEthernet0/1 going Up
*Mar  1 00:07:55.879: OSPF: Send hello to 224.0.0.5 area 0 on FastEthernet0/1 from 10.0.12
3.245
*Mar  1 00:07:55.943: OSPF: Rcv hello from 10.0.30.1 area 0 from FastEthernet0/1 10.0.123.
246
*Mar  1 00:07:55.947: OSPF: 2 Way Communication to 10.0.30.1 on FastEthernet0/1, state 2WA
Y
*Mar  1 00:07:55.947: OSPF: Backup seen Event before WAIT timer on FastEthernet0/1
*Mar  1 00:07:55.947: OSPF: DR/BDR election on FastEthernet0/1
*Mar  1 00:07:55.947: OSPF: Elect BDR 10.0.123.241
R1(config-if)#exi
*Mar  1 00:07:55.951: OSPF: Elect DR 10.0.30.1
*Mar  1 00:07:55.951: OSPF: Elect BDR 10.0.123.241
```

```
R1(config-if)#exit
*Mar  1 00:07:57.227: OSPF: Send hello to 224.0.0.5 area 0 on Serial0/0 from 10.0.123.241
*Mar  1 00:07:57.231: OSPF: Send hello to 224.0.0.5 area 0 on FastEthernet0/0 from 10.0.0.
2
*Mar  1 00:07:57.823: OSPF: Rcv hello from 10.0.30.1 area 0 from FastEthernet0/1 10.0.123.
246
*Mar  1 00:07:57.823: OSPF: End of hello processing
R1(config-if)#exit
*Mar  1 00:07:57.863: %LINK-3-UPDOWN: Interface FastEthernet0/1, changed state to up
*Mar  1 00:07:58.863: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet0/1, cha
nged state to up
R1(config-if)#exit
R1(config)#
*Mar  1 00:08:00.955: OSPF: Send DBD to 10.0.30.1 on FastEthernet0/1 seq 0x170E opt 0x52 f
lag 0x7 len 32
*Mar  1 00:08:00.955: OSPF: Retransmitting DBD to 10.0.30.1 on FastEthernet0/1 [1]
*Mar  1 00:08:00.991: OSPF: Rcv DBD from 10.0.30.1 on FastEthernet0/1 seq 0x234 opt 0x52 f
lag 0x7 len 32  mtu 1500 state EXSTART
*Mar  1 00:08:00.991: OSPF: First DBD and we are not SLAVE
*Mar  1 00:08:00.999: OSPF: Rcv DBD from 10.0.30.1 on FastEthernet0/1 seq 0x170E opt 0x52
flag 0x2 len 132  mtu 1500 state EXSTART
*Mar  1 00:08:00.999: OSPF: NBR Negotiation Done. We are the MASTER
*Mar  1 00:08:01.003: OSPF: Send DBD to 10.0.30.1 on FastEthernet0/1 seq 0x170F opt 0x52 f
lag 0x3 len 132
*Mar  1 00:08:01.023: OSPF: Rcv DBD from 10.0.30.1 on FastEthernet0/1 seq 0x170F opt 0x52
flag 0x0 len 32  mtu 1500 state EXCHANGE
*Mar  1 00:08:01.023: OSPF: Send DBD to 10.0.30.1 on FastEthernet0/1 seq 0x1710 opt 0x52 f
lag 0x1 len 32
*Mar  1 00:08:01.039: OSPF: Rcv DBD from 10.0.30.1 on FastEthernet0/1 seq 0x1710 opt 0x52
flag 0x0 len 32  mtu 1500 state EXCHANGE
*Mar  1 00:08:01.039: OSPF: Exchange Done with 10.0.30.1 on FastEthernet0/1
*Mar  1 00:08:01.039: OSPF: Synchronized with 10.0.30.1 on FastEthernet0/1, state FULL
*Mar  1 00:08:01.043: %OSPF-5-ADJCHG: Process 77, Nbr 10.0.30.1 on FastEthernet0/1 from LO
ADING 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 10.0.123.246 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 00:00:34
    Neighbor is up for 00:20:47
    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 00:00:31
    Neighbor is up for 00:28:27
    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
```

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
interface f0/0
ip address 10.0.123.251 255.255.255.248
no shutdown
exit
interface loopback 0
ip address 10.0.40.1 255.255.255.252
exit
router ospf 77
network 10.0.0.0 0.0.255.255 area 0
exit
```

```
R4#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R4(config)#interface f0/0
R4(config-if)#ip address 10.0.123.251 255.255.255.248
R4(config-if)#no shutdown
R4(config-if)#exit
R4(config)#
*Mar  1 18:19:22.151: %LINK-3-UPDOWN: Interface FastEthernet0/0, changed state to up
*Mar  1 18:19:23.151: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet0/0, chan
ged state to up
R4(config)#interface f0/0
R4(config-if)#exit
R4(config)#interface loopback 0
R4(config-if)#ip addr
*Mar  1 18:27:05.035: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback0, changed st
ate to up
R4(config-if)#ip address 10.0.40.1 255.255.255.252
R4(config-if)#exit
R4(config)#router ospf 77
R4(config-router)#network 10.0.0.0 0.0.255.255 area 0
R4(config-router)#exit
R4(config)#exit
```

R6 配置命令：

```
conf t
interface f0/0
ip address 10.0.123.252 255.255.255.248
no shutdown exit
interface loopback 0
ip address 10.0.60.1 255.255.255.252
exit
router ospf 77
network 10.0.0.0 0.0.255.255 area 0
exit
```

```
R6#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R6(config)#interface f0/0
R6(config-if)#ip address 10.0.123.252 255.255.255.248
R6(config-if)#no shutdown
R6(config-if)#exit
R6(config)#
*Mar  1 18:28:30.727: %LINK-3-UPDOWN: Interface FastEthernet0/0, changed state to up
*Mar  1 18:28:31.727: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet0/0, cha
ged state to up
R6(config)#interface loopback 0
R6(config-if)#ip addre
*Mar  1 18:28:39.179: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback0, changed s
ate to up
R6(config-if)#ip address 10.0.60.1 255.255.255.252
R6(config-if)#exit
R6(config)#router ospf 77
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         00:00:34    10.0.123.249    FastEthernet0/0
10.0.30.1         1   FULL/BDR        00:00:37    10.0.123.250    FastEthernet0/0
10.0.60.1         1   2WAY/DROTHER    00:00:32    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         00:00:33    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#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R4(config)#interface f0/1
R4(config-if)#ip address 10.1.0.1 255.255.255.0
R4(config-if)#no shutdown
R4(config-if)#exit
R4(config)#router ospf 77
R4(config-router)#network 10.0.0.0 0.0.255.255 area 0
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)#interface f0/1
R5(config-if)# ip address 10.1.0.2 255.255.255.0
R5(config-if)# no shutdown
R5(config)#interface f0/0
R5(config-if)# ip address 10.1.1.2 255.255.255.0
R5(config-if)# no shutdown
R5(config)#interface loopback 0
R5(config-if)# ip address 10.1.50.1 255.255.255.252
R5(config)# router ospf 77
R5(config-router)# network 10.1.0.0 0.0.255.255 area 1
```

PC3 配置命令：

```
PC3> ip 10.1.1.3 255.255.255.0 10.1.1.2
Checking for duplicate address...
PC3 : 10.1.1.3 255.255.255.0 gateway 10.1.1.2
```

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。

```
R2#show ip route
Codes: C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static rout
       o - ODR, P - periodic downloaded static route

Gateway of last resort is not set

     10.0.0.0/8 is variably subnetted, 11 subnets, 4 masks
O IA    10.1.1.0/24 [110/21] via 10.0.123.251, 00:03:20, FastEthernet1/0
O       10.0.0.0/24 [110/21] via 10.0.123.250, 00:09:49, FastEthernet1/0
O IA    10.1.0.0/24 [110/11] via 10.0.123.251, 00:09:49, 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, 00:09:49, FastEthernet1/0
O       10.0.60.1/32 [110/2] via 10.0.123.252, 00:09:51, FastEthernet1/0
O IA    10.1.50.1/32 [110/12] via 10.0.123.251, 00:03:21, 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, 00:09:51, 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__f0/1__接口发出。

```
R5#show ip route
Codes: C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route

Gateway of last resort is not set

     10.0.0.0/8 is variably subnetted, 11 subnets, 4 masks
C       10.1.1.0/24 is directly connected, FastEthernet0/0
O IA    10.0.0.0/24 [110/40] via 10.1.0.1, 00:04:43, 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, 00:04:43, FastEthernet0/1
O IA    10.0.20.1/32 [110/21] via 10.1.0.1, 00:04:43, FastEthernet0/1
O IA    10.0.40.1/32 [110/11] via 10.1.0.1, 00:04:43, FastEthernet0/1
O IA    10.0.60.1/32 [110/21] via 10.1.0.1, 00:04:44, 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, 00:04:44, FastEthernet0/1
O IA    10.0.123.244/30 [110/30] via 10.1.0.1, 00:04:44, FastEthernet0/1
O IA    10.0.123.248/29 [110/20] via 10.1.0.1, 00:04:44, FastEthernet0/1
```

PC3→PC1 的连通性：

```
PC3> ping 10.0.0.1

10.0.0.1 icmp_seq=1 timeout
84 bytes from 10.0.0.1 icmp_seq=2 ttl=60 time=67.692 ms
84 bytes from 10.0.0.1 icmp_seq=3 ttl=60 time=52.630 ms
84 bytes from 10.0.0.1 icmp_seq=4 ttl=60 time=53.299 ms
84 bytes from 10.0.0.1 icmp_seq=5 ttl=60 time=76.888 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 10.0.40.1 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 77)

                Router Link States (Area 0)

Link ID         ADV Router      Age         Seq#       Checksum Link count
10.0.20.1       10.0.20.1       100         0x80000029 0x000F67 5
10.0.30.1       10.0.30.1       205         0x80000028 0x0007A0 2
10.0.40.1       10.0.40.1       844         0x80000003 0x005E1D 2
10.0.60.1       10.0.60.1       1174        0x80000002 0x00C27D 2
10.0.123.241    10.0.123.241    185         0x80000006 0x005B16 4

                Net Link States (Area 0)

Link ID         ADV Router      Age         Seq#       Checksum
10.0.123.246    10.0.30.1       205         0x80000003 0x002EC6
10.0.123.249    10.0.20.1       1178        0x80000028 0x00D7D8

                Summary Net Link States (Area 0)

Link ID         ADV Router      Age         Seq#       Checksum
10.1.0.0        10.0.40.1       839         0x80000001 0x00E50F
10.1.1.0        10.0.40.1       449         0x80000001 0x003FAA
10.1.50.1       10.0.40.1       449         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 10.0.40.1 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 (10.1.50.1) (Process ID 77)

                Router Link States (Area 1)

Link ID         ADV Router      Age         Seq#       Checksum Link count
10.0.40.1       10.0.40.1       558         0x80000002 0x00B0F8 1
10.1.50.1       10.1.50.1       557         0x80000002 0x00DB42 3

                Net Link States (Area 1)

Link ID         ADV Router      Age         Seq#       Checksum
10.1.0.1        10.0.40.1       558         0x80000001 0x005C2D

                Summary Net Link States (Area 1)

Link ID         ADV Router      Age         Seq#       Checksum
10.0.0.0        10.0.40.1       948         0x80000001 0x00BA27
10.0.1.0        10.0.40.1       948         0x80000001 0x004B9F
10.0.20.1       10.0.40.1       948         0x80000001 0x0015CA
10.0.40.1       10.0.40.1       948         0x80000001 0x00D302
10.0.60.1       10.0.40.1       948         0x80000001 0x005B5C
10.0.123.240    10.0.40.1       948         0x80000001 0x00AAA1
10.0.123.244    10.0.40.1       948         0x80000001 0x00641A
10.0.123.248    10.0.40.1       949         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 、10.0.20.1 、 10.0.40.1 、

10.0.60.1 、 10.0.123.240 、10.0.123.244 、 10.0.123.248 。

```
            OSPF Router with ID (10.0.40.1) (Process ID 77)

                Router Link States (Area 0)

Link ID         ADV Router      Age         Seq#       Checksum Link count
10.0.20.1       10.0.20.1       199         0x80000029 0x000F67 5
10.0.30.1       10.0.30.1       303         0x80000028 0x0007A0 2
10.0.40.1       10.0.40.1       940         0x80000003 0x005E1D 2
10.0.60.1       10.0.60.1       1272        0x80000002 0x00C27D 2
10.0.123.241    10.0.123.241    284         0x80000006 0x005B16 4

                Net Link States (Area 0)

Link ID         ADV Router      Age         Seq#       Checksum
10.0.123.246    10.0.30.1       303         0x80000003 0x002EC6
10.0.123.249    10.0.20.1       1276        0x80000028 0x00D7D8

                Summary Net Link States (Area 0)

Link ID         ADV Router      Age         Seq#       Checksum
10.1.0.0        10.0.40.1       935         0x80000001 0x00E50F
10.1.1.0        10.0.40.1       545         0x80000001 0x003FAA
10.1.50.1       10.0.40.1       545         0x80000001 0x00BD03

                Router Link States (Area 1)

Link ID         ADV Router      Age         Seq#       Checksum Link count
10.0.40.1       10.0.40.1       552         0x80000002 0x00B0F8 1
10.1.50.1       10.1.50.1       553         0x80000002 0x00DB42 3

                Net Link States (Area 1)

Link ID         ADV Router      Age         Seq#       Checksum
10.1.0.1        10.0.40.1       552         0x80000001 0x005C2D

                Summary Net Link States (Area 1)

Link ID         ADV Router      Age         Seq#       Checksum
10.0.0.0        10.0.40.1       942         0x80000001 0x00BA27
10.0.1.0        10.0.40.1       942         0x80000001 0x004B9F
10.0.20.1       10.0.40.1       942         0x80000001 0x0015CA
10.0.40.1       10.0.40.1       942         0x80000001 0x00D302
10.0.60.1       10.0.40.1       942         0x80000001 0x005B5C
10.0.123.240    10.0.40.1       942         0x80000001 0x00AAA1
10.0.123.244    10.0.40.1       942         0x80000001 0x00641A
10.0.123.248    10.0.40.1       944         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 77 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 9
```

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 77 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
```

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 address 10.2.0.1 255.255.255.0
R6(config-if)# no shutdown
R6(config)# router ospf 77
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 address 10.2.0.2 255.255.255.0
R8(config-if)# no shutdown
R8(config)#interface f0/0
R8(config-if)# ip address 10.2.2.1 255.255.255.0
R8(config-if)# no shutdown
R8(config)#interface f1/0
R8(config-if)# ip address 10.2.1.2 255.255.255.0
R8(config-if)# no shutdown
R8(config)#interface loopback 0
R8(config-if)# ip address 10.2.80.1 255.255.255.252
R8(config)# router ospf 77
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 、10.1.0.0 、10.1.50.1 .。

```
R8#show ip route
Codes: C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route

Gateway of last resort is not set

     10.0.0.0/8 is variably subnetted, 15 subnets, 4 masks
C       10.2.0.0/24 is directly connected, FastEthernet0/1
C       10.2.1.0/24 is directly connected, FastEthernet1/0
C       10.2.2.0/24 is directly connected, FastEthernet0/0
O IA    10.1.1.0/24 [110/40] via 10.2.0.1, 00:00:46, FastEthernet0/1
O IA    10.0.0.0/24 [110/40] via 10.2.0.1, 00:00:46, FastEthernet0/1
O IA    10.1.0.0/24 [110/30] via 10.2.0.1, 00:00:46, FastEthernet0/1
O IA    10.0.1.0/24 [110/30] via 10.2.0.1, 00:00:46, FastEthernet0/1
O IA    10.0.20.1/32 [110/21] via 10.2.0.1, 00:00:48, FastEthernet0/1
O IA    10.0.40.1/32 [110/21] via 10.2.0.1, 00:00:48, FastEthernet0/1
O IA    10.0.60.1/32 [110/11] via 10.2.0.1, 00:00:48, FastEthernet0/1
O IA    10.1.50.1/32 [110/31] via 10.2.0.1, 00:00:48, FastEthernet0/1
C       10.2.80.0/30 is directly connected, Loopback0
```

PC4→PC1 的连通性：

```
PC4> ping 10.0.0.1

84 bytes from 10.0.0.1 icmp_seq=1 ttl=60 time=82.613 ms
84 bytes from 10.0.0.1 icmp_seq=2 ttl=60 time=70.150 ms
84 bytes from 10.0.0.1 icmp_seq=3 ttl=60 time=83.812 ms
84 bytes from 10.0.0.1 icmp_seq=4 ttl=60 time=76.637 ms
84 bytes from 10.0.0.1 icmp_seq=5 ttl=60 time=80.524 ms
```

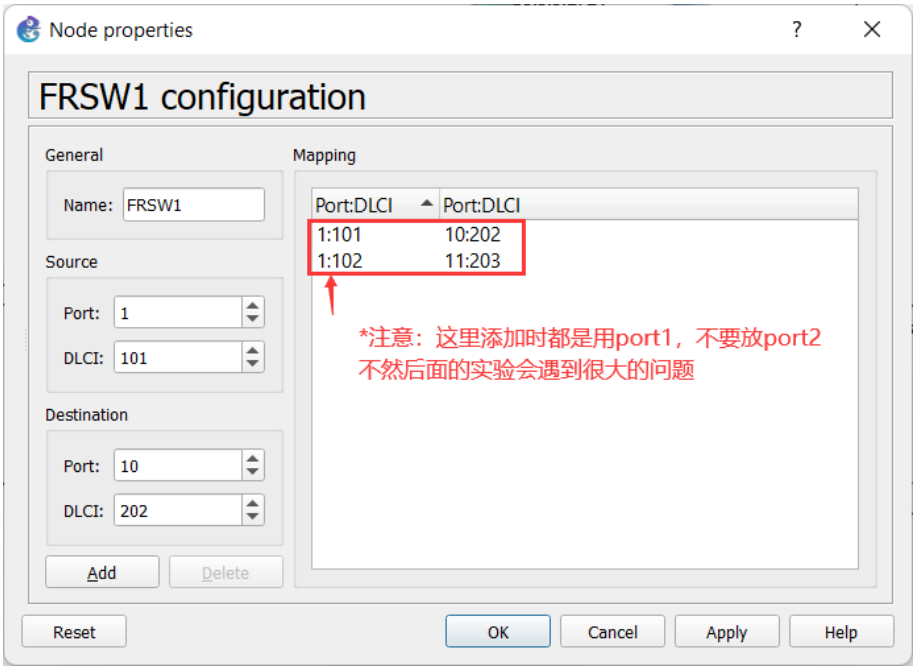
PC4→PC3 的连通性：

```
PC4> ping 10.1.1.3

84 bytes from 10.1.1.3 icmp_seq=1 ttl=60 time=86.546 ms
84 bytes from 10.1.1.3 icmp_seq=2 ttl=60 time=77.322 ms
84 bytes from 10.1.1.3 icmp_seq=3 ttl=60 time=79.814 ms
84 bytes from 10.1.1.3 icmp_seq=4 ttl=60 time=81.653 ms
84 bytes from 10.1.1.3 icmp_seq=5 ttl=60 time=79.766 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：

```
R5#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R5(config)#interface 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
*Mar  1 20:14:29.970: %LINK-3-UPDOWN: Interface Serial0/0, changed state to up
*Mar  1 20:14:40.970: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial0/0, changed
state to up
R5(config)#interface s0/0.1 multipoint
R5(config-subif)#ip address 10.1.2.5 255.255.255.0
R5(config-subif)#frame-relay interface-dlci 101
R5(config-fr-dlci)#no shutdown
R5(config-subif)#exit
R5(config)#interface s0/0.2 multipoint
```

```
R5(config-subif)#ip address 10.1.2.6 255.255.255.0
R5(config-subif)#frame-relay interface-dlci 102
R5(config-fr-dlci)#no shutdown
R5(config-subif)#exit
R5(config)#router ospf 77
R5(config-router)#network 10.1.0.0 0.0.255.255 area 1
R5(config-router)#exit
R5(config)#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 address 10.2.2.2 255.255.255.0
R7(config-if)# no shutdown
R7(config)#interface s0/0
R7(config-if)# ip address 10.1.2.7 255.255.255.0 （IP 地址）
R7(config-if)# encapsulation frame-relay （封装协议）
R7(config-if)# frame-relay lmi-type ANSI （LMI）
R7(config-if)# frame-relay interface-dlci 202 （DLCI）
R7(config-if)# no shutdown （激活）
R7(config)#interface loopback 0
R7(config-if)# ip address 10.2.70.1 255.255.255.252
R7(config)# router ospf 77
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 10.1.2.5 dlci 202(0xCA,0x30A0), dynamic,
              broadcast,, 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 10.1.2.7 dlci 101(0x65,0x1850), dynamic,
              broadcast,, 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 10.1.2.5

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 = 1/6/24 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 address 10.3.1.2 255.255.255.0
R9(config-if)# no shutdown
R9(config)#interface s0/0
R9(config-if)# ip address 10.1.2.8 255.255.255.0 （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 shutdown （激活）
R9(config)#interface loopback 0
R9(config-if)# ip address 10.3.90.1 255.255.255.252
R9(config)# router ospf 77
R9(config-router)# network 10.3.0.0 0.0.255.255 area 3
R9(config-router)# network 10.1.0.0 0.0.255.255 area 1
```

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

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

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 = 1/93/452 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 10.1.2.7

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

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:

```
*Mar  1 00:00:33.395: %LINEPROTO-5-UPDOWN: Line protocol on Interface Seria
R-5#sh 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 0x52
    LLS Options is 0x1 (LR)
    Dead timer due in 00:00:37
    Neighbor is up for 00:00:42
    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
R-5#
```

在 R7 上查看邻居关系:

```
R7#show ip ospf neighbor detail
 Neighbor 10.0.80.1, interface address 10.2.2.1
    In the area 2 via interface FastEthernet0/0
    Neighbor priority is 1, State is FULL, 6 state changes
    DR is 10.2.2.1 BDR is 10.2.2.2
    Options is 0x52
    LLS Options is 0x1 (LR)
    Dead timer due in 00:00:30
    Neighbor is up for 00:19:49
    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
```

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 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 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 10.1.0.2 BDR is 10.1.0.1
    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 20:00:35
    Index 1/1, retransmission queue length 0, number of retransmission 3
    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 10.1.2.8
    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 00:01:58
    Neighbor is up for 00:00:29
    Index 2/2, retransmission queue length 0, number of retransmission 3
    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 10.2.70.1, interface address 10.1.2.7
    In the area 1 via interface Serial0/0.1
    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 00:01:41
    Neighbor is up for 00:00:20
    Index 3/3, 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
```

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, 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 00:01:36
    Neighbor is up for 00:01:04
    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 10.2.2.1
    In the area 2 via interface FastEthernet0/0
    Neighbor priority is 1, State is FULL, 6 state changes
    DR is 10.2.2.1 BDR is 10.2.2.2
    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 20:01:22
    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 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 00:01:38
    Neighbor is up for 00:01:51
    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
```

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) 10.0.40.1 宣告的，而 R7 作为 Area 1 和 Area 2 的 ABR，却没有向 Area 1 宣告 Area 2 的路由信息，是因为所有的 Area 都只和 Area 0 进行路由信息交换。

```
R5#show ip ospf database

            OSPF Router with ID (10.1.50.1) (Process ID 77)

                Router Link States (Area 1)

Link ID         ADV Router      Age         Seq#       Checksum Link count
10.0.40.1       10.0.40.1       1629        0x80000025 0x007411 1
10.1.50.1       10.1.50.1       203         0x8000002C 0x00AA85 7
10.2.70.1       10.2.70.1       204         0x80000028 0x00159B 2
10.3.90.1       10.3.90.1       723         0x8000002B 0x00B5CB 2

                Net Link States (Area 1)

Link ID         ADV Router      Age         Seq#       Checksum
10.1.0.2        10.1.50.1       1664        0x80000024 0x0091C8

                Summary Net Link States (Area 1)

Link ID         ADV Router      Age         Seq#       Checksum
10.0.0.0        10.0.40.1       1629        0x80000025 0x00724B
10.0.1.0        10.0.40.1       1629        0x80000024 0x0005C2
10.0.20.1       10.0.40.1       1629        0x80000024 0x00CEED
10.0.40.1       10.0.40.1       1629        0x80000024 0x008D25
10.0.60.1       10.0.40.1       1629        0x80000024 0x00157F
10.0.123.240    10.0.40.1       1633        0x80000024 0x0064C4
10.0.123.244    10.0.40.1       1633        0x80000024 0x001E3D
10.0.123.248    10.0.40.1       1633        0x80000024 0x0079EB
10.2.0.0        10.0.40.1       1633        0x80000024 0x00F7CE
10.2.1.0        10.0.40.1       1633        0x80000024 0x00F6CD
10.2.2.0        10.0.40.1       1633        0x80000024 0x004674
10.2.70.1       10.0.40.1       1633        0x80000024 0x00571D
10.2.80.1       10.0.40.1       1633        0x80000024 0x0084EF
```

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) 10.0.60.1 宣告的，而 R7 作为 Area 1 和 Area 2 的 ABR，也没有向 Area 2 宣告 Area 1 的路由信息，。

```
R8#show ip ospf database

            OSPF Router with ID (10.2.80.1) (Process ID 77)

                Router Link States (Area 2)

Link ID         ADV Router      Age         Seq#       Checksum Link count
10.0.60.1       10.0.60.1       49          0x80000026 0x001D3D 1
10.2.70.1       10.2.70.1       422         0x80000026 0x00A931 2
10.2.80.1       10.2.80.1       356         0x80000026 0x0074F5 4

                Net Link States (Area 2)

Link ID         ADV Router      Age         Seq#       Checksum
10.2.0.2        10.2.80.1       356         0x80000025 0x00C441
10.2.2.1        10.2.80.1       356         0x80000025 0x0053A5

                Summary Net Link States (Area 2)

Link ID         ADV Router      Age         Seq#       Checksum
10.0.0.0        10.0.60.1       49          0x80000026 0x00E3C4
10.0.1.0        10.0.60.1       49          0x80000025 0x00763C
10.0.20.1       10.0.60.1       49          0x80000025 0x004067
10.0.40.1       10.0.60.1       49          0x80000025 0x006330
10.0.60.1       10.0.60.1       49          0x80000025 0x002267
10.0.123.240    10.0.60.1       50          0x80000025 0x00D53E
10.0.123.244    10.0.60.1       50          0x80000025 0x008FB6
10.0.123.248    10.0.60.1       50          0x80000025 0x00EA65
10.1.0.0        10.0.60.1       50          0x80000025 0x00753D
10.1.1.0        10.0.60.1       50          0x80000025 0x00CED8
10.1.2.5        10.0.60.1       348         0x80000001 0x00755A
10.1.2.6        10.0.60.1       338         0x80000001 0x006B63
10.1.2.7        10.0.60.1       320         0x80000001 0x00E3A9
10.1.2.8        10.0.60.1       340         0x80000001 0x00D9B2
10.1.50.1       10.0.60.1       51          0x80000025 0x004D31
```

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) 10.0.40.1 宣告的，

Area 2 所有的的聚合路由都是由区域边界路由器(ABR) 10.0.60.1 宣告的。

```
                Summary Net Link States (Area 1)

Link ID         ADV Router      Age         Seq#       Checksum
10.0.0.0        10.0.40.1       1805        0x80000025 0x00724B
10.0.1.0        10.0.40.1       1805        0x80000024 0x0005C2
10.0.20.1       10.0.40.1       1805        0x80000024 0x00CEED
10.0.40.1       10.0.40.1       1805        0x80000024 0x008D25
10.0.60.1       10.0.40.1       1805        0x80000024 0x00157F
10.0.123.240    10.0.40.1       1806        0x80000024 0x0064C4
10.0.123.244    10.0.40.1       1806        0x80000024 0x001E3D
10.0.123.248    10.0.40.1       1806        0x80000024 0x0079EB
10.2.0.0        10.0.40.1       1806        0x80000024 0x00F7CE
10.2.1.0        10.0.40.1       1806        0x80000024 0x00F6CD
10.2.2.0        10.0.40.1       1806        0x80000024 0x004674
10.2.70.1       10.0.40.1       1806        0x80000024 0x00571D
10.2.80.1       10.0.40.1       1806        0x80000024 0x0084EF
```

```
                Summary Net Link States (Area 2)

Link ID         ADV Router      Age         Seq#       Checksum
10.0.0.0        10.0.60.1       99          0x80000026 0x00E3C4
10.0.1.0        10.0.60.1       103         0x80000025 0x00763C
10.0.20.1       10.0.60.1       103         0x80000025 0x004067
10.0.40.1       10.0.60.1       103         0x80000025 0x006330
10.0.60.1       10.0.60.1       103         0x80000025 0x002267
10.0.123.240    10.0.60.1       103         0x80000025 0x00D53E
10.0.123.244    10.0.60.1       103         0x80000025 0x008FB6
10.0.123.248    10.0.60.1       103         0x80000025 0x00EA65
10.1.0.0        10.0.60.1       103         0x80000025 0x00753D
10.1.1.0        10.0.60.1       103         0x80000025 0x00CED8
10.1.2.5        10.0.60.1       400         0x80000001 0x00755A
10.1.2.6        10.0.60.1       391         0x80000001 0x006B63
10.1.2.7        10.0.60.1       371         0x80000001 0x00E3A9
10.1.2.8        10.0.60.1       391         0x80000001 0x00D9B2
10.1.50.1       10.0.60.1       104         0x80000025 0x004D31
```

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 10.1.1.3
Routing entry for 10.1.1.0/24
  Known via "ospf 77", distance 110, metric 40, type inter area
  Last update from 10.2.0.1 on FastEthernet0/1, 20:08:08 ago
  Routing Descriptor Blocks:
  * 10.2.0.1, from 10.0.60.1, 20:08:08 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 10.1.1.0 的路由已经不存在。

```
R6(config)#interface f0/0
R6(config-if)#shutdown
R6(config-if)#e
*Mar  1 20:11:20.298: %OSPF-5-ADJCHG: Process 77, Nbr 10.0.20.1 on FastEthernet0/0 from FULL to DOWN, Neighb
or Down: Interface down or detached
```

```
R8#show ip route 10.1.1.3
% Subnet not in table
```

```
     10.0.0.0/8 is variably subnetted, 6 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
C       10.2.2.0/24 is directly connected, FastEthernet0/0
O IA    10.0.60.1/32 [110/11] via 10.2.0.1, 20:10:30, FastEthernet0/1
O       10.2.70.1/32 [110/11] via 10.2.2.2, 20:10:30, FastEthernet0/0
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 10.1.1.0 的路由是存在的，但是由于 Area 2 和 Area 1 不直接交换路由信息，R7 没有向 Area 2 宣告路由的存在。

```
R7#show ip route 10.1.1.3
Routing entry for 10.1.1.0/24
  Known via "ospf 77", distance 110, metric 74, type intra area
  Last update from 10.1.2.5 on Serial0/0, 00:12:32 ago
  Routing Descriptor Blocks:
  * 10.1.2.5, from 10.1.50.1, 00:12:32 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。

```
R6(config)#interface f0/0
R6(config-if)#no shutdown
R6(config-if)#exit
R6(config)#
*Mar  1 20:14:34.630: %LINK-3-UPDOWN: Interface FastEthernet0/0, changed state to up
*Mar  1 20:14:35.630: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet0/0, changed state to up
```

```
R8#show ip route 10.1.1.3
Routing entry for 10.1.1.0/24
  Known via "ospf 77", distance 110, metric 40, type inter area
  Last update from 10.2.0.1 on FastEthernet0/1, 00:00:31 ago
  Routing Descriptor Blocks:
  * 10.2.0.1, from 10.0.60.1, 00:00:31 ago, via FastEthernet0/1
      Route metric is 40, traffic share count is 1
```

已恢复

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 address 10.3.1.3 255.255.255.0
R10(config-if)# no shutdown
R10(config)#interface f0/0
R10(config-if)# ip address 10.3.2.2 255.255.255.0
R10(config-if)# no shutdown
R10(config)#interface loopback 0
R10(config-if)# ip address 10.3.100.1 255.255.255.252
R10(config)# router ospf 77
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 77)

                Router Link States (Area 3)

Link ID         ADV Router      Age         Seq#       Checksum Link count
10.3.90.1       10.3.90.1       8           0x80000026 0x00FC9D 2
10.3.100.1      10.3.100.1      7           0x80000002 0x00185E 3

                Net Link States (Area 3)

Link ID         ADV Router      Age         Seq#       Checksum
10.3.1.2        10.3.90.1       8           0x80000001 0x0038AE
```

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, 3 masks
C       10.3.1.0/24 is directly connected, FastEthernet0/1
C       10.3.2.0/24 is directly connected, FastEthernet0/0
O       10.3.90.1/32 [110/11] via 10.3.1.2, 00:05:29, FastEthernet0/1
C       10.3.100.0/30 is directly connected, Loopback0
R10#
```

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 77
R4(config-router)# area 1 virtual-link 10.3.90.1
```

R9 配置命令：

```
R9(config)# router ospf 77
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 area 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_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 area 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 00:00:01
    Adjacency State FULL (Hello suppressed)
    Index 1/3, retransmission queue length 0, number of retransmission 0
    First 0x0(0)/0x0(0) Next 0x0(0)/0x0(0)
    Last retransmission scan length is 0, maximum is 0
    Last retransmission scan time is 0 msec, maximum is 0 msec
```

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/  -            -        10.1.2.8        OSPF_VL0
10.0.20.1         1   FULL/DROTHER    00:00:31    10.0.123.249    FastEthernet0/0
10.0.30.1         1   FULL/BDR        00:00:30    10.0.123.250    FastEthernet0/0
10.0.60.1         1   FULL/DROTHER    00:00:30    10.0.123.252    FastEthernet0/0
10.1.50.1         1   FULL/DR         00:00:33    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/  -         00:01:40    10.1.2.6        Serial0/0
10.3.100.1        1   FULL/BDR        00:00:31    10.3.1.3        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, 24 subnets, 4 masks
O IA    10.1.2.8/32 [110/10] via 10.3.1.2, 00:07:52, FastEthernet0/1
C       10.3.1.0/24 is directly connected, FastEthernet0/1
O IA    10.2.0.0/24 [110/104] via 10.3.1.2, 00:05:02, FastEthernet0/1
O IA    10.2.1.0/24 [110/105] via 10.3.1.2, 00:05:02, FastEthernet0/1
O IA    10.2.2.0/24 [110/114] via 10.3.1.2, 00:05:02, FastEthernet0/1
O IA    10.1.1.0/24 [110/84] via 10.3.1.2, 00:07:52, FastEthernet0/1   PC3
O IA    10.0.0.0/24 [110/114] via 10.3.1.2, 00:05:03, FastEthernet0/1  PC1
C       10.3.2.0/24 is directly connected, FastEthernet0/0
O IA    10.1.0.0/24 [110/84] via 10.3.1.2, 00:07:53, FastEthernet0/1
O IA    10.0.1.0/24 [110/104] via 10.3.1.2, 00:05:03, FastEthernet0/1  PC2
O IA    10.1.2.5/32 [110/74] via 10.3.1.2, 00:07:53, FastEthernet0/1
O IA    10.1.2.7/32 [110/138] via 10.3.1.2, 00:07:53, FastEthernet0/1
O IA    10.1.2.6/32 [110/74] via 10.3.1.2, 00:07:54, FastEthernet0/1
O IA    10.0.20.1/32 [110/95] via 10.3.1.2, 00:05:04, FastEthernet0/1
O IA    10.0.40.1/32 [110/85] via 10.3.1.2, 00:05:04, FastEthernet0/1
O IA    10.0.60.1/32 [110/95] via 10.3.1.2, 00:05:04, FastEthernet0/1
O IA    10.1.50.1/32 [110/75] via 10.3.1.2, 00:07:54, FastEthernet0/1
O IA    10.2.70.1/32 [110/115] via 10.3.1.2, 00:05:04, FastEthernet0/1
O       10.3.90.1/32 [110/11] via 10.3.1.2, 00:07:54, FastEthernet0/1
O IA    10.2.80.1/32 [110/105] via 10.3.1.2, 00:05:04, FastEthernet0/1
C       10.3.100.0/30 is directly connected, Loopback0
O IA    10.0.123.240/30 [110/158] via 10.3.1.2, 00:05:04, FastEthernet0/1
O IA    10.0.123.244/30 [110/104] via 10.3.1.2, 00:05:04, FastEthernet0/1
O IA    10.0.123.248/29 [110/94] via 10.3.1.2, 00:05:04, 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 77)

                Router Link States (Area 3)

Link ID         ADV Router      Age         Seq#       Checksum Link count
10.3.90.1       10.3.90.1       818         0x80000027 0x00FD9A 2
10.3.100.1      10.3.100.1      1397        0x80000002 0x00185E 3

                Net Link States (Area 3)

Link ID         ADV Router      Age         Seq#       Checksum
10.3.1.2        10.3.90.1       1398        0x80000001 0x0038AE

                Summary Net Link States (Area 3)

Link ID         ADV Router      Age         Seq#       Checksum
10.0.0.0        10.3.90.1       643         0x80000001 0x002A38
10.0.1.0        10.3.90.1       643         0x80000001 0x00BAB0
10.0.20.1       10.3.90.1       643         0x80000001 0x0084DB
10.0.40.1       10.3.90.1       643         0x80000001 0x004313
10.0.60.1       10.3.90.1       643         0x80000001 0x00CA6D
10.0.123.240    10.3.90.1       643         0x80000001 0x001AB2
10.0.123.244    10.3.90.1       643         0x80000001 0x00D32B
10.0.123.248    10.3.90.1       645         0x80000001 0x002FD9
10.1.0.0        10.3.90.1       820         0x80000001 0x00F08E
10.1.1.0        10.3.90.1       820         0x80000001 0x00E598
10.1.2.5        10.3.90.1       820         0x80000001 0x00443E
10.1.2.6        10.3.90.1       820         0x80000001 0x003A47
10.1.2.7        10.3.90.1       820         0x80000001 0x00B28D
10.1.2.8        10.3.90.1       820         0x80000001 0x00A31C
10.1.50.1       10.3.90.1       820         0x80000001 0x0064F0
10.2.0.0        10.3.90.1       645         0x80000001 0x00ADBC
10.2.1.0        10.3.90.1       645         0x80000001 0x00ACBB
10.2.2.0        10.3.90.1       645         0x80000001 0x00FB62
10.2.70.1       10.3.90.1       645         0x80000001 0x000D0B
10.2.80.1       10.3.90.1       645         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, 25 subnets, 5 masks
C       10.3.1.0/24 is directly connected, FastEthernet0/1
O IA    10.2.0.0/24 [110/94] via 10.1.2.6, 00:00:04, Serial0/0
O IA    10.2.1.0/24 [110/95] via 10.1.2.6, 00:00:04, Serial0/0
C       10.1.2.0/24 is directly connected, Serial0/0
O IA    10.2.2.0/24 [110/104] via 10.1.2.6, 00:00:04, Serial0/0
O       10.1.1.0/24 [110/74] via 10.1.2.6, 00:00:04, Serial0/0
O       10.0.0.0/24 [110/104] via 10.1.2.6, 00:00:04, Serial0/0
O       10.0.0.0/16 is a summary, 00:00:06, Null0
O       10.3.2.0/24 [110/20] via 10.3.1.3, 00:00:06, FastEthernet0/1
O       10.1.0.0/24 [110/74] via 10.1.2.6, 00:00:06, Serial0/0
O       10.0.1.0/24 [110/94] via 10.1.2.6, 00:00:06, Serial0/0
O       10.1.2.5/32 [110/64] via 10.1.2.6, 00:00:06, Serial0/0
O       10.1.2.7/32 [110/128] via 10.1.2.6, 00:00:07, Serial0/0
O       10.1.2.6/32 [110/64] via 10.1.2.6, 00:00:07, Serial0/0
O       10.0.20.1/32 [110/85] via 10.1.2.6, 00:00:07, Serial0/0
O       10.0.40.1/32 [110/75] via 10.1.2.6, 00:00:07, Serial0/0
O       10.0.60.1/32 [110/85] via 10.1.2.6, 00:00:07, Serial0/0
O       10.1.50.1/32 [110/65] via 10.1.2.6, 00:00:07, Serial0/0
O IA    10.2.70.1/32 [110/105] via 10.1.2.6, 00:00:07, Serial0/0
C       10.3.90.0/30 is directly connected, Loopback0
O IA    10.2.80.1/32 [110/95] via 10.1.2.6, 00:00:07, Serial0/0
O       10.3.100.1/32 [110/11] via 10.3.1.3, 00:00:07, FastEthernet0/1
O       10.0.123.240/30 [110/148] via 10.1.2.6, 00:00:07, Serial0/0
O       10.0.123.244/30 [110/94] via 10.1.2.6, 00:00:07, Serial0/0
O       10.0.123.248/29 [110/84] via 10.1.2.6, 00:00:07, 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 10.3.1.2 ，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, 17 subnets, 4 masks
O IA    10.1.2.8/32 [110/10] via 10.3.1.2, 00:17:01, FastEthernet0/1
C       10.3.1.0/24 is directly connected, FastEthernet0/1
O IA    10.2.0.0/24 [110/104] via 10.3.1.2, 00:14:10, FastEthernet0/1
O IA    10.2.1.0/24 [110/105] via 10.3.1.2, 00:14:10, FastEthernet0/1
O IA    10.2.2.0/24 [110/114] via 10.3.1.2, 00:14:10, FastEthernet0/1
O IA    10.1.1.0/24 [110/84] via 10.3.1.2, 00:17:01, FastEthernet0/1
O IA    10.0.0.0/16 [110/85] via 10.3.1.2, 00:01:37, FastEthernet0/1
C       10.3.2.0/24 is directly connected, FastEthernet0/0
O IA    10.1.0.0/24 [110/84] via 10.3.1.2, 00:17:02, FastEthernet0/1
O IA    10.1.2.5/32 [110/74] via 10.3.1.2, 00:17:02, FastEthernet0/1
O IA    10.1.2.7/32 [110/138] via 10.3.1.2, 00:17:02, FastEthernet0/1
O IA    10.1.2.6/32 [110/74] via 10.3.1.2, 00:17:02, FastEthernet0/1
O IA    10.1.50.1/32 [110/75] via 10.3.1.2, 00:17:06, FastEthernet0/1
O IA    10.2.70.1/32 [110/115] via 10.3.1.2, 00:14:16, FastEthernet0/1
O       10.3.90.1/32 [110/11] via 10.3.1.2, 00:17:06, FastEthernet0/1
O IA    10.2.80.1/32 [110/105] via 10.3.1.2, 00:14:16, 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。

查看 config 文件夹！（输入 wr 保持配置信息，然后右键点击路由器 Export config）

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：不一定姚相同。进程号仅是对路由器本身而言，不同路由器之间不会干扰，相互独立，因此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：如果没有手工指定 Router ID，并且没有给回环接口配置 IP 地址，则会从本地逻辑接口 IP 地址最高的一个，如果没有逻辑接口，则会选择物理接口 IP 地址最高的。

- 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：不会，OSPF 将仍然保持原 Router ID。只有重新配置系统的 Router ID 或者 OSPF 的 Router ID，并且重新启动 OSPF 进程后，才会进行 Router ID 的重新选取。如果有回环接口，重新设置的就是使用回环接口。

- 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：这个不是子网掩码，时通配符掩码，0 位表示需要检查，不能忽略，1 位表示不需要检查，可忽略。对于 0.0.255.255，说明前 16 位必须匹配，后 16 位无关。

- 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：是的。OSPF 协议中非 area 0 区域的路由信息是不能互相直接传递的，都需要 area 0 来交换。虚拟路的作用是传播区域间的路由信息，将没有与 Area 0 有直接物理连接的区域虚拟连接到 area 0，使得非主干区域与主干区域连通。

- 为什么要在区域边界路由器上进行路由合并？

  答：当网络较大时，使得路由表更为精简，可以有效减少路由信息，从而更容易维护。

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：

- 对 OSPF 协议有了更深入的理解但还不是很懂。
- 对 router ID 方面的相关内容还不是很了解。
- 为什么需要手工指定那个 ospf 的进程号？

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：

在配置 Frame-relay switch 时，添加错了 port，应该要是 port:1, dlci:101 和 port:1, dlci:102（✔），而我添加成 port:1, dlci:101 和 port:2, dlci:102（✘），导致在配置 R9 的 frame-relay 时 mapping 出错（连接不上 10.1.2.6），耗费了我一下午的时间一直在找哪里出错了，所以做实验时一定要谨慎，不要填错信息。

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

在开始实验前也遇到了一些麻烦，就是虚拟机的内存不够，导致我画完图后，一启动 GNS3 就会宕机，然后我就一直尝试重启，也重装了好多次，添加新的 Cisco 设备，这些方法都是不可行的，所以在开始实验前记得把虚拟机的内存调整至 4G。

你对本实验安排有哪些更好的建议呢？欢迎献计献策：收集各位同学们在实验过程中遇到的问题并进行整理，然后公开给下一届的学生提供出错信息的解决方案，以免学生们在做实验时浪费非常多的时间。（因为在网上 GNS3 出错信息的解决方案并不是很多）