

# 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

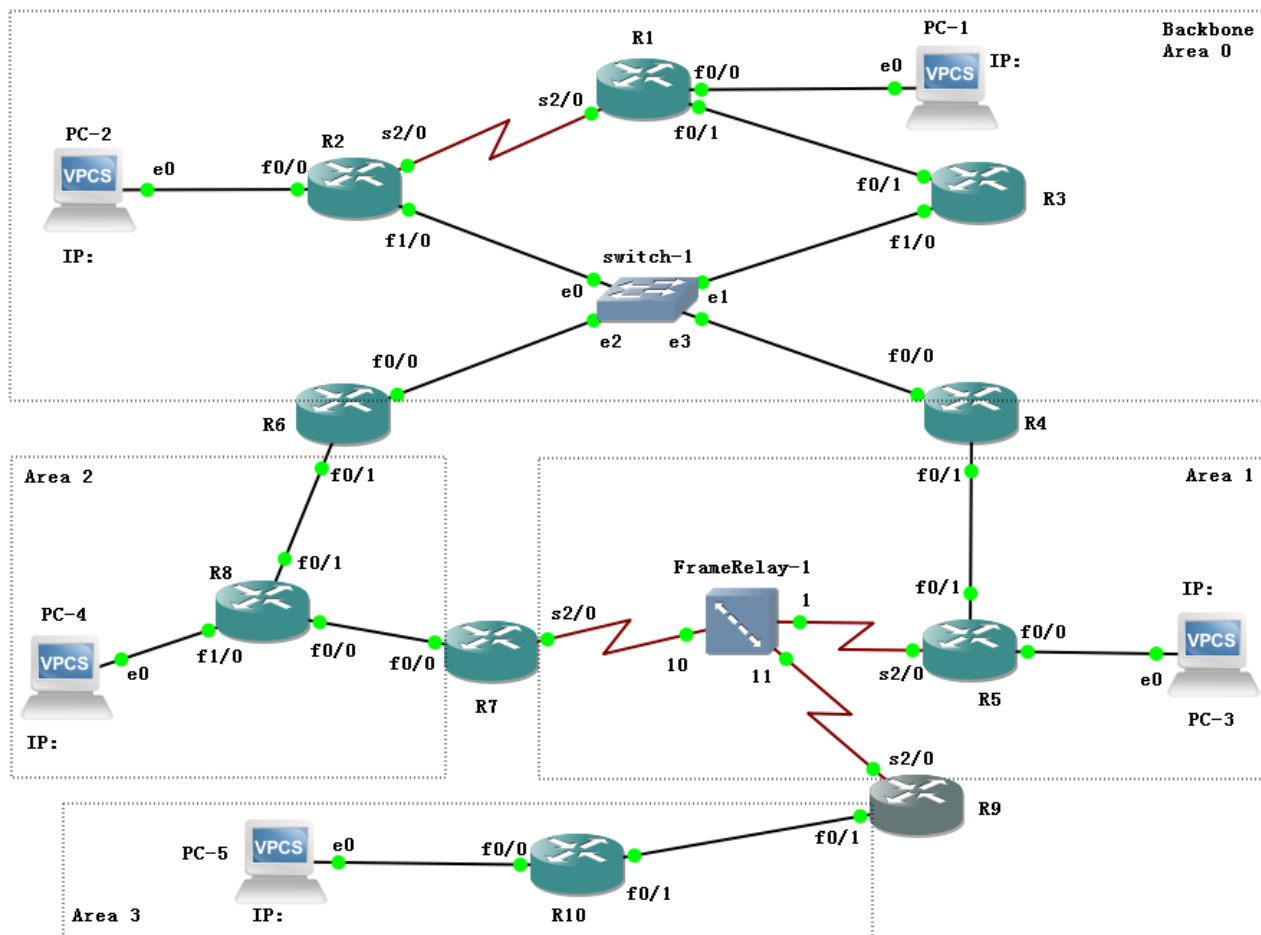
PC 机、路由器、Console 连接线、直联网络线、交叉网络线（如果物理设备不足，可以使用模拟软件）。

## 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：

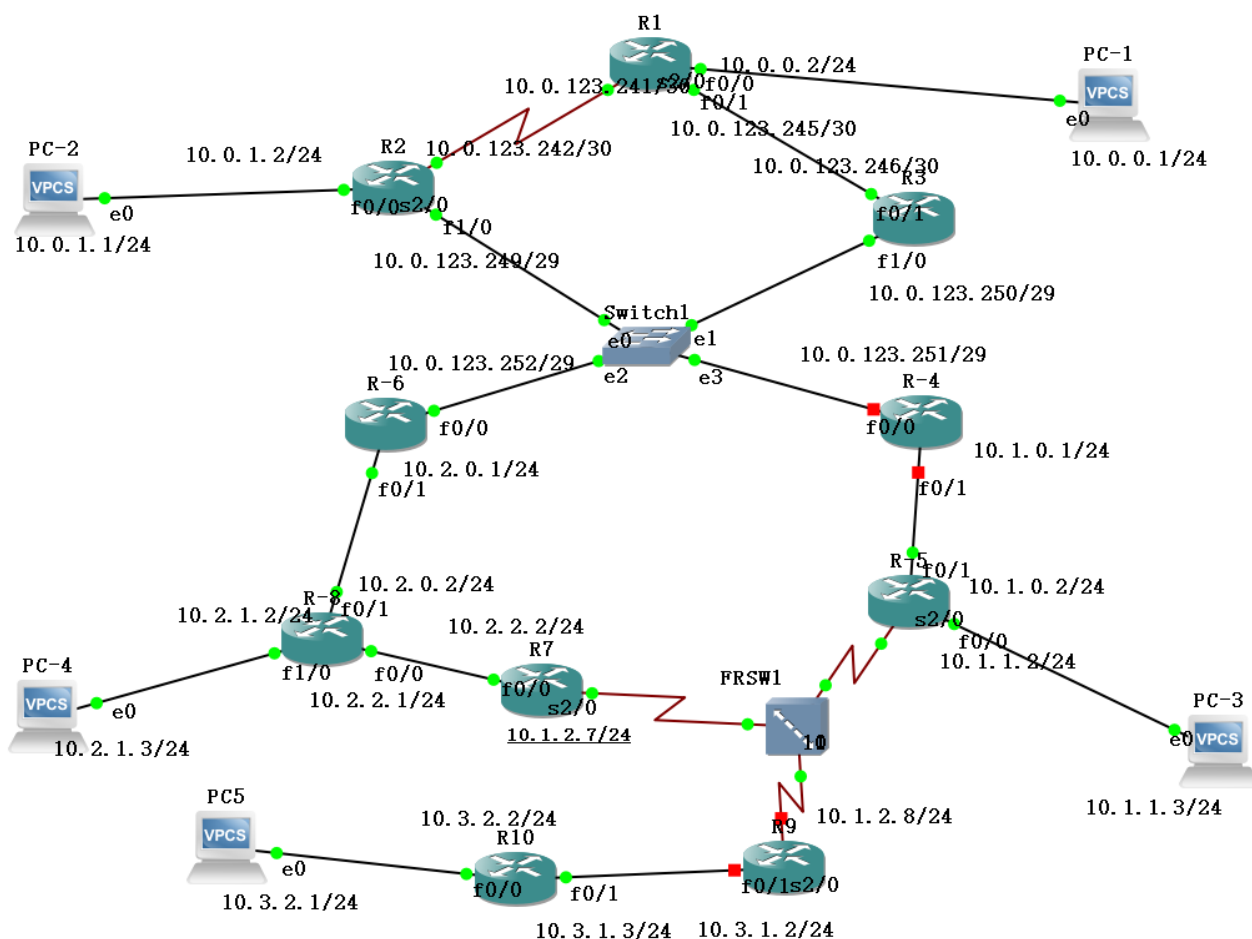
```
Router(config-router)# area <area-id> range <ip_net> <mask>
```

## 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，直接粘贴文字即可（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 addr 10.0.0.2 255.255.255.0
R1(config-if)#no shut
R1(config-if)#ex
R1(config)#interface f0/1
R1(config-if)#ip addr 10.0.123.245 255.255.255.252
R1(config-if)#no shut
R1(config-if)#ex
R1(config)#interface s2/0
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 shut
R1(config-if)#ex
R1(config)#ex
R1#
*Mar  1 00:00:23.091: %SYS-5-CONFIG_I: Configured from console by console
R1#
*Mar  1 00:00:25.015: %LINK-3-UPDOWN: Interface FastEthernet0/0, changed state to up
*Mar  1 00:00:25.059: %LINK-3-UPDOWN: Interface FastEthernet0/1, changed state to up
*Mar  1 00:00:25.083: %LINK-3-UPDOWN: Interface Serial0/1, changed state to up
*Mar  1 00:00:26.015: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet0/0, changed state to
up
R1#
```

**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 addr 10.0.1.2 255.255.255.0
R2(config-if)#no shut
R2(config-if)#ex
R2(config)#interface f1/0
R2(config-if)#ip addr 10.0.123.249 255.255.255.248
R2(config-if)#no shut
R2(config-if)#ex
R2(config)#interface s2/0
R2(config-if)#ip addr 10.0.123.242 255.255.255.252
R2(config-if)#encapsulation hdlc
R2(config-if)#no shut
```

```
R2(config-if)#ex
```

```
R2(config)#ex
```

```
R2#
```

```
*Mar  1 00:16:20.951: %SYS-5-CONFIG_I: Configured from console by console
```

```
R2#
```

```
*Mar  1 00:16:22.883: %LINK-3-UPDOWN: Interface FastEthernet0/0, changed state to up
```

```
*Mar  1 00:16:22.927: %LINK-3-UPDOWN: Interface FastEthernet1/0, changed state to up
```

```
*Mar  1 00:16:22.947: %LINK-3-UPDOWN: Interface Serial2/0, changed state to up
```

```
*Mar  1 00:16:23.883: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet0/0, changed state to up
```

```
R2#
```

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 addr 10.0.123.246 255.255.255.252
```

```
R3(config-if)#no shut
```

```
R3(config-if)#ex
```

```
R3(config)#interface f1/0
```

```
R3(config-if)#ip addr 10.0.123.250 255.255.255.248
```

```
R3(config-if)#no shut
```

```
R3(config-if)#ex
```

```
R3(config)#ex
```

```
R3#
```

```
*Mar  1 00:19:14.587: %SYS-5-CONFIG_I: Configured from console by console
```

```
R3#
```

```
*Mar  1 00:19:16.539: %LINK-3-UPDOWN: Interface FastEthernet0/1, changed state to up
```

```
*Mar  1 00:19:16.579: %LINK-3-UPDOWN: Interface FastEthernet1/0, changed state to up
```

```
*Mar  1 00:19:17.539: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet0/1, changed state to up
```

Ping 测试结果截图

PC1→R1:

```
PC-1> ping 10.0.0.2
84 bytes from 10.0.0.2 icmp_seq=1 ttl=255 time=20.235 ms
84 bytes from 10.0.0.2 icmp_seq=2 ttl=255 time=4.307 ms
84 bytes from 10.0.0.2 icmp_seq=3 ttl=255 time=9.371 ms
84 bytes from 10.0.0.2 icmp_seq=4 ttl=255 time=14.358 ms
84 bytes from 10.0.0.2 icmp_seq=5 ttl=255 time=3.199 ms
```

PC2→R2:

```
PC-2> ping 10.0.1.2
84 bytes from 10.0.1.2 icmp_seq=1 ttl=255 time=10.295 ms
84 bytes from 10.0.1.2 icmp_seq=2 ttl=255 time=11.288 ms
84 bytes from 10.0.1.2 icmp_seq=3 ttl=255 time=6.366 ms
84 bytes from 10.0.1.2 icmp_seq=4 ttl=255 time=8.271 ms
84 bytes from 10.0.1.2 icmp_seq=5 ttl=255 time=11.326 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）；

Conf t

Router rip

Network 10.0.123.244

Network 10.0.123.248

Version 2

Ex

Ex

**R1 配置命令：**

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)#Ex

R1(config)#Ex

**R2 配置命令：**

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)#Ex

R2(config)#Ex

**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)#Ex

R3(config)#Ex

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 R2



```

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

Gateway of last resort is not set

    10.0.0.0/8 is variably subnetted, 5 subnets, 3 masks
C       10.0.0.0/24 is directly connected, FastEthernet0/0
R       10.0.1.0/24 [120/1] via 10.0.123.242, 00:00:24, Serial2/0
C       10.0.123.240/30 is directly connected, Serial2/0
C       10.0.123.244/30 is directly connected, FastEthernet0/1
R       10.0.123.248/29 [120/1] via 10.0.123.246, 00:00:13, FastEthernet0/1
        [120/1] via 10.0.123.242, 00:00:24, Serial2/0
R1#

```

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 R1

```

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, 00:00:22, Serial2/0
C       10.0.1.0/24 is directly connected, FastEthernet0/0
C       10.0.123.240/30 is directly connected, Serial2/0
R       10.0.123.244/30 [120/1] via 10.0.123.250, 00:00:28, FastEthernet1/0
        [120/1] via 10.0.123.241, 00:00:22, Serial2/0
C       10.0.123.248/29 is directly connected, FastEthernet1/0
R2#
R2#

```

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, 00:00:25, FastEthernet0/1
R       10.0.1.0/24 [120/1] via 10.0.123.249, 00:00:24, FastEthernet1/0
R       10.0.123.240/30 [120/1] via 10.0.123.249, 00:00:24, FastEthernet1/0
        [120/1] via 10.0.123.245, 00:00:25, FastEthernet0/1
C       10.0.123.244/30 is directly connected, FastEthernet0/1
C       10.0.123.248/29 is directly connected, FastEthernet1/0
R3#

```

PC1→PC2 的路由跟踪：（经过的路由器顺序是 R1、R2）

```

R1#tracert 10.0.1.1
Trace to 10.0.1.1, 8 hops max, press Ctrl+C to stop
 1  10.0.0.2    13.291 ms  10.340 ms  10.895 ms
 2  10.0.123.242 32.420 ms  31.245 ms  32.281 ms
 3  *10.0.1.1   43.207 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）。

Conf t

Router ospf 60

Network 10.0.0.0 0.0.255.255 area 0

Ex

ex

**R1 配置命令：**

R1(config)#Router ospf 60

R1(config-router)#Network 10.0.0.0 0.0.255.255 area 0

R1(config-router)#ex

R1(config)#ex

R1#

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）。

Conf t

Interface loopback 0

Ip address 10.0.20.1 255.255.255.252

ex

Router ospf 60

Network 10.0.0.0 0.0.255.255 area 0

Ex

ex

**R2 配置命令：**

R2(config)#Interface loopback 0

R2(config-if)#Ip address 10.0.20.1 255.255.255.252

R2(config-if)#ex

R2(config)#Router ospf 60

R2(config-router)#Network 10.0.0.0 0.0.255.255 area 0

R2(config-router)#Ex

R2(config)#ex

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。

Conf t

Router ospf 60

Router-id 10.0.30.1

Network 10.0.0.0 0.0.255.255 area 0

Ex

ex

**R3 配置命令：**

```
R3#Conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R3(config)#Router ospf 60
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)#Ex
R3(config)#ex
```

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 60)

      Router Link States (Area 0)

Link ID        ADV Router    Age          Seq#          Checksum Link
10.0.20.1      10.0.20.1     60           0x80000003   0x00B0F0 5
10.0.30.1      10.0.30.1     61           0x80000003   0x002CAA 2
10.0.123.245   10.0.123.245  94           0x80000003   0x004D32 4

      Net Link States (Area 0)

Link ID        ADV Router    Age          Seq#          Checksum
10.0.123.245   10.0.123.245  94           0x80000001   0x00DFC1
10.0.123.249   10.0.20.1     60           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 10.0.123.249、10.0.123.245。

R2 的 OSPF 数据库：

```
R2#sh ip ospf database

      OSPF Router with ID (10.0.20.1) (Process ID 60)

      Router Link States (Area 0)

Link ID        ADV Router    Age          Seq#          Checksum Link count
10.0.20.1      10.0.20.1     420          0x80000003   0x00B0F0 5
10.0.30.1      10.0.30.1     421          0x80000003   0x002CAA 2
10.0.123.245   10.0.123.245  456          0x80000003   0x004D32 4

      Net Link States (Area 0)

Link ID        ADV Router    Age          Seq#          Checksum
10.0.123.245   10.0.123.245  456          0x80000001   0x00DFC1
10.0.123.249   10.0.20.1     420          0x80000001   0x00FC5D
R2#10.0.20.110.0.30.110.0.123.24510.0.123.24510.0.123.249
```

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 60)

        Router Link States (Area 0)

Link ID        ADV Router    Age      Seq#          Checksum Link count
10.0.20.1      10.0.20.1      609      0x80000003   0x00B0F0 5
10.0.30.1      10.0.30.1      608      0x80000003   0x002CAA 2
10.0.123.245   10.0.123.245   643      0x80000003   0x004D32 4

        Net Link States (Area 0)

Link ID        ADV Router    Age      Seq#          Checksum
10.0.123.245   10.0.123.245   644      0x80000001   0x00DFC1
10.0.123.249   10.0.20.1      610      0x80000001   0x00FC5D
R3#

```

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）

```

Serial2/0 is up, line protocol is up
Internet Address 10.0.123.241/30, Area 0
Process ID 60, 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 00:00:08
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 0 msec
Neighbor Count is 1, Adjacent neighbor count is 1
  Adjacent with neighbor 10.0.20.1
Suppress hello for 0 neighbor(s)

```

R1 的 f0/1:（f0/1 连接的网络类型为 BROADCAST，Cost=1，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 60, Router ID 10.0.123.245, Network Type BROADCAST, Cost: 1
  Transmit Delay is 1 sec, State DR, Priority 1
  Designated Router (ID) 10.0.123.245, Interface address 10.0.123.245
  Backup Designated router (ID) 10.0.30.1, Interface address 10.0.123.246
  Timer intervals configured, Hello 10, Dead 40, Wait 40, Retransmit 5
    oob-resync timeout 40
    Hello due in 00:00:06
  Index 2/2, flood queue length 0
  Next 0x0(0)/0x0(0)
  Last flood scan length is 2, maximum is 2
  Last flood scan time is 0 msec, maximum is 0 msec
  Neighbor Count is 1, Adjacent neighbor count is 1
    Adjacent with neighbor 10.0.30.1 (Backup Designated Router)
  Suppress hello for 0 neighbor(s)
FastEthernet0/0 is up, line protocol is up

```

R1 的 f0/0: (f0/1 连接的网络类型为 BROADCAST，Cost= 1，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 60, Router ID 10.0.123.245, Network Type BROADCAST, Cost: 1
  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 00:00:02
  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, 6 subnets, 4 masks
C    10.0.0.0/24 is directly connected, FastEthernet0/0
O    10.0.1.0/24 [110/3] via 10.0.123.246, 00:17:11, FastEthernet0/1
O    10.0.20.1/32 [110/3] via 10.0.123.246, 00:17:11, FastEthernet0/1
C    10.0.123.240/30 is directly connected, Serial2/0
C    10.0.123.244/30 is directly connected, FastEthernet0/1
O    10.0.123.248/29 [110/2] via 10.0.123.246, 00:17:11, 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)

```

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 [110/3] via 10.0.123.250, 00:18:35, 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, Serial2/0
O   10.0.123.244/30 [110/2] via 10.0.123.250, 00:18:35, 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, 6 subnets, 4 masks
O   10.0.0.0/24 [110/2] via 10.0.123.245, 00:19:17, FastEthernet0/1
O   10.0.1.0/24 [110/2] via 10.0.123.249, 00:19:17, FastEthernet1/0
O   10.0.20.1/32 [110/2] via 10.0.123.249, 00:19:17, FastEthernet1/0
O   10.0.123.240/30 [110/65] via 10.0.123.249, 00:19:17, FastEthernet1/0
    [110/65] via 10.0.123.245, 00:19:17, 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    、    R3    、    R2    )

```

PC-1> trace 10.0.1.1
Trace to 10.0.1.1, 8 hops max, press Ctrl+C to stop
 1  10.0.0.2    9.438 ms  9.209 ms  10.260 ms
 2  10.0.123.246 29.216 ms 31.239 ms 31.329 ms
 3  10.0.123.249 52.147 ms 52.122 ms 53.249 ms
 4  **10.0.1.1  66.086 ms (ICMP type:3, code:3, Destination port unreachable)
PC-1>

```

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#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 [110/65] via 10.0.123.242, 00:04:22, Serial2/0
O   10.0.20.1/32 [110/65] via 10.0.123.242, 00:04:22, Serial2/0
C   10.0.123.240/30 is directly connected, Serial2/0
O   10.0.123.244/30 [110/66] via 10.0.123.242, 00:04:22, Serial2/0
O   10.0.123.248/29 [110/65] via 10.0.123.242, 00:04:22, Serial2/0
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 s2/0 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#sh ip ospf database

      OSPF Router with ID (10.0.123.241) (Process ID 60)

      Router Link States (Area 0)

Link ID        ADV Router    Age          Seq#           Checksum Link count
10.0.20.1      10.0.20.1      7            0x80000007    0x005051 5
10.0.30.1      10.0.30.1     834          0x80000005    0x00D380 2
10.0.123.241   10.0.123.241   7            0x80000002    0x00C8C6 3
10.0.123.245   10.0.123.245   997          0x80000004    0x008401 3

      Net Link States (Area 0)

Link ID        ADV Router    Age          Seq#           Checksum
10.0.123.249   10.0.20.1     900          0x80000002    0x00FA5E
```

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

R1 和 R3 重新建立邻接关系的事件记录：（从图可知，邻接关系建立经历了 5 个状态，分别是 state INIT、

state 2WAY、state EXSTART、state EXCHANGE、state FULL）

```
*Mar 1 00:03:05.607: OSPF: Send hello to 224.0.0.5 area 0 on Serial2/0 from 10.0.123.241
*Mar 1 00:03:05.951: OSPF: Interface FastEthernet0/1 going Up
*Mar 1 00:03:05.951: OSPF: Send hello to 224.0.0.5 area 0 on FastEthernet0/1 from 10.0.123.245
R1(config-if)#ex
R1(config)#
*Mar 1 00:03:07.943: %LINK-3-UPDOWN: Interface FastEthernet0/1, changed state to up
*Mar 1 00:03:08.943: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet0/1, changed state to up
R1(config)#
*Mar 1 00:03:10.407: OSPF: Rcv hello from 10.0.30.1 area 0 from FastEthernet0/1 10.0.123.246
*Mar 1 00:03:10.407: OSPF: 2 Way Communication to 10.0.30.1 on FastEthernet0/1, state 2WAY
*Mar 1 00:03:10.407: OSPF: Backup seen Event before WAIT timer on FastEthernet0/1
*Mar 1 00:03:10.407: OSPF: DR/BDR election on FastEthernet0/1
*Mar 1 00:03:10.407: OSPF: Elect BDR 10.0.123.241
*Mar 1 00:03:10.407: OSPF: Elect DR 10.0.30.1
*Mar 1 00:03:10.407: OSPF: Elect BDR 10.0.123.241
*Mar 1 00:03:10.407: OSPF: Elect DR 10.0.30.1
*Mar 1 00:03:10.407: DR: 10.0.30.1 (Id) BDR: 10.0.123.241 (Id)
R1(config)#
*Mar 1 00:03:10.407: OSPF: Send DBD to 10.0.30.1 on FastEthernet0/1 seq 0x1F46 opt 0x52 flag 0x7 len 32
*Mar 1 00:03:10.407: OSPF: End of hello processing
R1(config)#
*Mar 1 00:03:11.839: OSPF: Rcv hello from 10.0.20.1 area 0 from Serial2/0 10.0.123.242
*Mar 1 00:03:11.839: OSPF: End of hello processing
R1(config)#
*Mar 1 00:03:15.407: OSPF: Send DBD to 10.0.30.1 on FastEthernet0/1 seq 0x1F46 opt 0x52 flag 0x7 len 32
*Mar 1 00:03:15.407: OSPF: Retransmitting DBD to 10.0.30.1 on FastEthernet0/1 [1]
*Mar 1 00:03:15.431: OSPF: Rcv DBD from 10.0.30.1 on FastEthernet0/1 seq 0x1A21 opt 0x52 flag 0x7 len 32 mtu 1500 state EXSTART
*Mar 1 00:03:15.431: OSPF: First DBD and we are not SLAVE
*Mar 1 00:03:15.439: OSPF: Rcv DBD from 10.0.30.1 on FastEthernet0/1 seq 0x1F46 opt 0x52 flag 0x2 len 132 mtu 1500 state EXSTART
*Mar 1 00:03:15.439: OSPF: NBR Negotiation Done. We are the MASTER
*Mar 1 00:03:15.439: OSPF: Send DBD to 10.0.30.1 on FastEthernet0/1 seq 0x1F47 opt 0x52 flag 0x3 len 132
*Mar 1 00:03:15.463: OSPF: Rcv DBD from 10.0.30.1 on FastEthernet0/1 seq 0x1F47 opt 0x52 flag 0x0 len 32 mtu 1500 state EXCHANGE
*Mar 1 00:03:15.463: OSPF: Send DBD to 10.0.30.1 on FastEthernet0/1 seq 0x1F48 opt 0x52 flag 0x1 len 32
*Mar 1 00:03:15.483: OSPF: Rcv DBD from 10.0.30.1 on FastEthernet0/1 seq 0x1F48 opt 0x52 flag 0x0 len 32 mtu 1500 state EXCHANGE
*Mar 1 00:03:15.483: OSPF: Exchange Done with 10.0.30.1 on FastEthernet0/1
*Mar 1 00:03:15.483: OSPF: Synchronized with 10.0.30.1 on FastEthernet0/1, state FULL
*Mar 1 00:03:15.483: %OSPF-5-ADJCHG: Process 60, Nbr 10.0.30.1 on FastEthernet0/1 from LOADING to FULL, Loading Done
R1(config)#
```



R1 的 OSPF 邻居详细信息:

```
R1#sh ip ospf neighbor de
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 0x52
  LLS Options is 0x1 (LR)
  Dead timer due in 00:00:38
  Neighbor is up for 00:07:51
  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 Serial2/0
  Neighbor priority is 0, State is FULL, 6 state changes
  DR is 0.0.0.0 BDR is 0.0.0.0
  Options is 0x52
  LLS Options is 0x1 (LR)
  Dead timer due in 00:00:30
  Neighbor is up for 00:10:35
  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
R1#
```

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 addr 10.0.123.251 255.255.255.248
no shut
ex
```

```
Interface loopback 0
Ip address 10.0.40.1 255.255.255.252
ex
```

```
Router ospf 60
Network 10.0.0.0 0.0.255.255 area 0
Ex
```

ex

R6 配置命令:

```
conf t
```



```
interface f0/0
ip addr 10.0.123.252 255.255.255.248
no shut
ex
```

```
Interface loopback 0
Ip address 10.0.60.1 255.255.255.252
ex
```

```
Router ospf 60
Network 10.0.0.0 0.0.255.255 area 0
Ex
```

ex

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）：

```
R-4#sh ip ospf neighbor
```

Neighbor ID	Pri	State	Dead Time	Address	Interface
10.0.20.1	1	FULL/DROTHER	00:00:34	10.0.123.249	FastEthernet0/0
10.0.30.1	1	FULL/DROTHER	00:00:33	10.0.123.250	FastEthernet0/0
10.0.60.1	1	FULL/DR	00:00:34	10.0.123.252	FastEthernet0/0

```
R-4#
```

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）：

```
Neighbor ID      Pri   State           Dead Time   Address      Interface
10.0.20.1         1    FULL/DROTHER    00:00:32    10.0.123.249 FastEthernet0/0
10.0.30.1         1    FULL/DROTHER    00:00:32    10.0.123.250 FastEthernet0/0
10.0.40.1         1    FULL/BDR        00:00:34    10.0.123.251 FastEthernet0/0
R-6#
```

### ---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）：

```
R-4(config)#interface f0/1
R-4(config-if)#ip addr 10.1.0.1 255.255.255.0
R-4(config-if)#no shut
R-4(config-if)#ex
R-4(config)#Router ospf 60
R-4(config-router)#Network 10.0.0.0 0.0.255.255 area 0
R-4(config-router)#Network 10.1.0.0 0.0.255.255 area 1
R-4(config-router)#Ex
```

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 10.1.1.2 255.255.255.0
R5(config-if)# no shut
R5(config)#interface loopback 0
R5(config-if)# Ip address 10.1.50.1 255.255.255.252
R5(config)# Router ospf 60
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 gateway 10.1.1.2

Checking for duplicate address...

PC1 : 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 FastEthernet1/0 接口发出。

```

R2#
10.0.0.0/8 is variably subnetted, 11 subnets, 4 masks
O IA 10.1.1.0/24 [110/3] via 10.0.123.251, 00:04:23, FastEthernet1/0
O 10.0.0.0/24 [110/3] via 10.0.123.250, 00:08:17, FastEthernet1/0
O IA 10.1.0.0/24 [110/2] via 10.0.123.251, 00:04:28, 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, 00:08:17, FastEthernet1/0
O 10.0.60.1/32 [110/2] via 10.0.123.252, 00:08:19, FastEthernet1/0
O IA 10.1.50.1/32 [110/3] via 10.0.123.251, 00:04:24, FastEthernet1/0
C 10.0.123.240/30 is directly connected, Serial2/0
O 10.0.123.244/30 [110/2] via 10.0.123.250, 00:08:19, 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 FastEthernet0/1 接口发出。

```

R5#
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 [110/4] via 10.1.0.1, 00:06:25, FastEthernet0/1
C 10.1.0.0/24 is directly connected, FastEthernet0/1
O IA 10.0.1.0/24 [110/3] via 10.1.0.1, 00:06:25, FastEthernet0/1
O IA 10.0.20.1/32 [110/3] via 10.1.0.1, 00:06:25, FastEthernet0/1
O IA 10.0.40.1/32 [110/2] via 10.1.0.1, 00:06:25, FastEthernet0/1
O IA 10.0.60.1/32 [110/3] via 10.1.0.1, 00:06:27, FastEthernet0/1
C 10.1.50.0/30 is directly connected, Loopback0
O IA 10.0.123.240/30 [110/66] via 10.1.0.1, 00:06:27, FastEthernet0/1
O IA 10.0.123.244/30 [110/3] via 10.1.0.1, 00:06:27, FastEthernet0/1
O IA 10.0.123.248/29 [110/2] via 10.1.0.1, 00:06:27, FastEthernet0/1
R5#

```

### PC3→PC1 的连通性:

```

PC-3> 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=56.092 ms
84 bytes from 10.0.0.1 icmp_seq=3 ttl=60 time=90.483 ms
84 bytes from 10.0.0.1 icmp_seq=4 ttl=60 time=73.317 ms
84 bytes from 10.0.0.1 icmp_seq=5 ttl=60 time=84.209 ms
PC-3>

```

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#sh ip ospf database

OSPF Router with ID (10.0.20.1) (Process ID 60)

Router Link States (Area 0)

Link ID        ADV Router    Age      Seq#          Checksum Link count
10.0.20.1      10.0.20.1     1770     0x80000003   0x003B63 5
10.0.30.1      10.0.30.1     1767     0x80000003   0x004A89 2
10.0.40.1      10.0.40.1     1334     0x80000005   0x008DF1 2
10.0.60.1      10.0.60.1     1770     0x80000002   0x00F550 2
10.0.123.245   10.0.123.245  1768     0x80000003   0x004D32 4

Net Link States (Area 0)

Link ID        ADV Router    Age      Seq#          Checksum
10.0.123.245   10.0.123.245  1768     0x80000001   0x00DFC1
10.0.123.252   10.0.60.1     1418     0x80000004   0x007F2A

Summary Net Link States (Area 0)

Link ID        ADV Router    Age      Seq#          Checksum
10.1.0.0       10.0.40.1     1099     0x80000003   0x008774
10.1.1.0       10.0.40.1     1094     0x80000001   0x008A71
10.1.50.1      10.0.40.1     1094     0x80000001   0x006366
```

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。

```
R-5#sh ip ospf database

OSPF Router with ID (10.1.50.1) (Process ID 60)

Router Link States (Area 1)

Link ID        ADV Router    Age      Seq#          Checksum Link count
10.0.40.1      10.0.40.1     950      0x80000002   0x000EA4 1
10.1.50.1      10.1.50.1     950      0x80000002   0x0051DE 3

Net Link States (Area 1)

Link ID        ADV Router    Age      Seq#          Checksum
10.1.0.1       10.0.40.1     951      0x80000001   0x005C2D

Summary Net Link States (Area 1)

Link ID        ADV Router    Age      Seq#          Checksum
10.0.0.0       10.0.40.1     1177     0x80000001   0x00AB51
10.0.1.0       10.0.40.1     1177     0x80000001   0x009666
10.0.20.1      10.0.40.1     1177     0x80000001   0x00BA2E
10.0.40.1      10.0.40.1     1177     0x80000001   0x00D302
10.0.60.1      10.0.40.1     1177     0x80000001   0x0001BF
10.0.123.240   10.0.40.1     1177     0x80000001   0x005005
10.0.123.244   10.0.40.1     1177     0x80000001   0x00AFE0
10.0.123.248   10.0.40.1     1193     0x80000001   0x00652C

R-5#
```

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。

```

Router Link States (Area 0)
Link ID      ADV Router    Age      Seq#         Checksum Link count
10.0.20.1    10.0.20.1     1921     0x80000003  0x003B63  5
10.0.30.1    10.0.30.1     1914     0x80000003  0x004A89  2
10.0.40.1    10.0.40.1     1479     0x80000005  0x008DF1  2
10.0.60.1    10.0.60.1     1918     0x80000002  0x00F550  2
10.0.123.245 10.0.123.245  1918     0x80000003  0x004D32  4

Net Link States (Area 0)
Link ID      ADV Router    Age      Seq#         Checksum
10.0.123.245 10.0.123.245  1917     0x80000001  0x00DFC1
10.0.123.252 10.0.60.1     1564     0x80000004  0x007F2A

Summary Net Link States (Area 0)
Link ID      ADV Router    Age      Seq#         Checksum
10.1.0.0     10.0.40.1     1244     0x80000003  0x008774
10.1.1.0     10.0.40.1     1239     0x80000001  0x008A71
--More
*Mar 1 00:26:21.255: %SYS-5-CONFIG_I: Configured from console by console--
10.1.50.1    10.0.40.1     1239     0x80000001  0x006366

Router Link States (Area 1)
Link ID      ADV Router    Age      Seq#         Checksum Link count
10.0.40.1    10.0.40.1     1260     0x80000002  0x00EA4  1
10.1.50.1    10.1.50.1     1261     0x80000002  0x0051DE  3

Net Link States (Area 1)
Link ID      ADV Router    Age      Seq#         Checksum
10.1.0.1     10.0.40.1     1261     0x80000001  0x005C2D

Summary Net Link States (Area 1)
Link ID      ADV Router    Age      Seq#         Checksum
10.0.0.0     10.0.40.1     1489     0x80000001  0x00AB51
10.0.1.0     10.0.40.1     1491     0x80000001  0x009666
10.0.20.1    10.0.40.1     1491     0x80000001  0x00BA2E
10.0.40.1    10.0.40.1     1491     0x80000001  0x00D302
10.0.60.1    10.0.40.1     1491     0x80000001  0x0001BF
10.0.123.240 10.0.40.1     1492     0x80000001  0x005005
10.0.123.244 10.0.40.1     1492     0x80000001  0x00AFE0
10.0.123.248 10.0.40.1     1492     0x80000001  0x00652C

```

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 60 internal Routing Table
Codes: i - Intra-area route, I - Inter-area route
i 10.0.40.1 [2] via 10.0.123.246, FastEthernet0/1, ABR, Area 0, SPF 7
R1#

```

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 60 internal Routing Table
Codes: i - Intra-area route, I - Inter-area route
i 10.0.40.1 [1] via 10.1.0.1, FastEthernet0/1, ABR, Area 1, SPF 3
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。

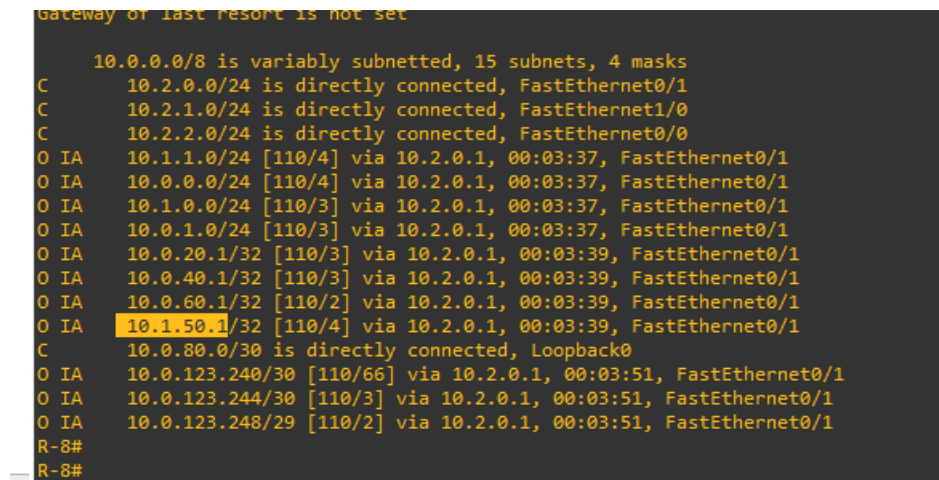
**R6 配置命令：**

```
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 60
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 10.2.2.1 255.255.255.0
R8(config-if)# no shut
R8(config)#interface f1/0
R8(config-if)# ip addr 10.2.1.2 255.255.255.0
R8(config-if)# no shut
R8(config)#interface loopback 0
R8(config-if)# Ip address 10.0.80.1 255.255.255.252
R8(config)# Router ospf 60
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。



```
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 [110/4] via 10.2.0.1, 00:03:37, FastEthernet0/1
O IA  10.0.0.0/24 [110/4] via 10.2.0.1, 00:03:37, FastEthernet0/1
O IA  10.1.0.0/24 [110/3] via 10.2.0.1, 00:03:37, FastEthernet0/1
O IA  10.0.1.0/24 [110/3] via 10.2.0.1, 00:03:37, FastEthernet0/1
O IA  10.0.20.1/32 [110/3] via 10.2.0.1, 00:03:39, FastEthernet0/1
O IA  10.0.40.1/32 [110/3] via 10.2.0.1, 00:03:39, FastEthernet0/1
O IA  10.0.60.1/32 [110/2] via 10.2.0.1, 00:03:39, FastEthernet0/1
O IA  10.1.50.1/32 [110/4] via 10.2.0.1, 00:03:39, FastEthernet0/1
C    10.0.80.0/30 is directly connected, Loopback0
O IA  10.0.123.240/30 [110/66] via 10.2.0.1, 00:03:51, FastEthernet0/1
O IA  10.0.123.244/30 [110/3] via 10.2.0.1, 00:03:51, FastEthernet0/1
O IA  10.0.123.248/29 [110/2] via 10.2.0.1, 00:03:51, FastEthernet0/1
R-8#
R-8#
```

**PC4→PC1 的连通性：**

```
PC-4> ping 10.0.0.1
10.0.0.1 icmp_seq=1 timeout
10.0.0.1 icmp_seq=2 timeout
84 bytes from 10.0.0.1 icmp_seq=3 ttl=60 time=73.085 ms
84 bytes from 10.0.0.1 icmp_seq=4 ttl=60 time=64.945 ms
84 bytes from 10.0.0.1 icmp_seq=5 ttl=60 time=84.920 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=69.113 ms
84 bytes from 10.1.1.3 icmp_seq=4 ttl=60 time=50.052 ms
84 bytes from 10.1.1.3 icmp_seq=5 ttl=60 time=65.924 ms

PC-4> █
```

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:

Port:DLCI	Port:DLCI
1:101	10:202
1:102	11:203
11:103	12:204

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:

```
R-5#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R-5(config)#interface s2/0
R-5(config-if)#encapsulation frame-relay
R-5(config-if)#frame-relay lmi-type ANSI
R-5(config-if)#no shut
R-5(config-if)#ex
R-5(config)#interface s2/0.1 multipoint
R-5(config-subif)#Ip address 10.1.2.5 255.255.255.0
R-5(config-subif)#frame-relay interface-dlci 101
R-5(config-fr-dlci)#no shut
R-5(config-subif)#ex
R-5(config)#
R-5(config)#interface s2/0.2 multipoint
R-5(config-subif)#Ip address 10.1.2.6 255.255.255.0
R-5(config-subif)#frame-relay interface-dlci 102
```

```

R-5(config-fr-dlci)#no shut
R-5(config-subif)#ex
R-5(config)#
R-5(config)#Router ospf 60
R-5(config-router)#Network 10.1.0.0 0.0.255.255 area 1
R-5(config-router)#Ex
R-5(config)#ex
R-5#
*Mar  1 00:10:03.315: %SYS-5-CONFIG_I: Configured from console by console
R-5#
*Mar  1 00:10:05.115: %LINK-3-UPDOWN: Interface Serial2/0, changed state to up
*Mar  1 00:10:06.115: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial2/0, changed state to up
R-5#

```

21. 给 R7 的各接口配置 IP 地址、激活，其中回环接口和 f0/0 接口属于 Area 2，s2/0 接口属于 Area 1，配置 s2/0 封装协议为 Frame Relay，DLCI 值设为 Frame Relay 交换机上 R5-R7 之间数据链路的相关 DLCI 值。

#### R7 配置命令：

```

R7(config)#interface f0/0
R7(config-if)# _____ ip addr 10.2.2.1 255.255.255.0 _____
R7(config-if)# no shut _____
R7(config)#interface s2/0
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 shut _____ (激活)
R7(config)#interface loopback 0
R7(config-if)# _____ Ip address 10.1.70.1 255.255.255.252 _____
R7(config)# _____ Router ospf 60 _____
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）：

```

*Mar  1 00:11:12.891: %SYS-5-CONFIG_I: Configured from console by console
R7#show frame-relay map
Serial2/0 (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）：

```

*Mar  1 00:10:00.115: %LINK-3-UPDOWN: Interface Serial2/0, changed state to up
R-5#show frame-relay map
Serial2/0.1 (up): ip 10.1.2.7 dlci 101(0x65,0x1850), dynamic,
                broadcast,, status defined, active
R-5#

```

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 = 12/18/28
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 10.3.1.2 255.255.255.0
R9(config-if)# no shut
R9(config)#interface s2/0
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 shut (激活)
R9(config)#interface loopback 0
R9(config-if)# Ip address 10.3.90.1 255.255.255.252
R9(config)# Router ospf 60
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
Serial2/0 (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）：

```

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 = 12/20/32 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 10.1.2.7

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)
R9#show ip ospf neighbor detail

```

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 Serial0/0/0 is down
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:

```

Success rate is 100 percent (3/3), round-trip min/avg/max = 12/18/28 ms
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-multipoint`），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:

```
R-5#sh ip ospf neighbor detail
Neighbor 10.3.90.1, interface address 10.1.2.8
  In the area 1 via interface Serial2/0.2
  Neighbor priority is 0, State is FULL, 6 state changes
  DR is 0.0.0.0 BDR is 0.0.0.0
  Options is 0x52
  LLS Options is 0x1 (LR)
  Dead timer due in 00:01:42
  Neighbor is up for 00:01:07
  Index 3/3, 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 10.1.70.1, interface address 10.1.2.7
  In the area 1 via interface Serial2/0.1
  Neighbor priority is 0, State is FULL, 6 state changes
  DR is 0.0.0.0 BDR is 0.0.0.0
  Options is 0x52
  LLS Options is 0x1 (LR)
  Dead timer due in 00:01:40
  Neighbor is up for 00:01:07
  Index 2/2, retransmission queue length 0, number of retransmission 2
  First 0x0(0)/0x0(0) Next 0x0(0)/0x0(0)
  Last retransmission scan length is 1, maximum is 1
  Last retransmission scan time is 0 msec, maximum is 0 msec
Neighbor 10.0.40.1, 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 00:00:39
  Neighbor is up for 00:02:00
  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#sh ip ospf neighbor de
R7#sh ip ospf neighbor detail
Neighbor 10.1.50.1, interface address 10.1.2.5
In the area 1 via interface Serial2/0
Neighbor priority is 0, State is FULL, 6 state changes
DR is 0.0.0.0 BDR is 0.0.0.0
Options is 0x52
LLS Options is 0x1 (LR)
Dead timer due in 00:01:47
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
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 00:00:33
Neighbor is up for 00:00:36
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
R7#

```

在 R9 上查看邻居关系:

```

R9#sh ip ospf neighbor de
R9#sh ip ospf neighbor detail
Neighbor 10.1.50.1, interface address 10.1.2.6
In the area 1 via interface Serial2/0
Neighbor priority is 0, State is FULL, 6 state changes
DR is 0.0.0.0 BDR is 0.0.0.0
Options is 0x52
LLS Options is 0x1 (LR)
Dead timer due in 00:01:43
Neighbor is up for 00:01:46
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
R9#

```

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。

```

R-5#show ip ospf database

        OSPF Router with ID (10.1.50.1) (Process ID 60)

          Router Link States (Area 1)

Link ID        ADV Router    Age      Seq#          Checksum Link count
10.0.40.1      10.0.40.1      196      0x8000000A   0x00FDAC 1
10.1.50.1      10.1.50.1      152      0x8000000E   0x00FE63 7
10.1.70.1      10.1.70.1      148      0x80000006   0x009BD5 3
10.3.90.1      10.3.90.1      153      0x80000002   0x0008A2 2


          Net Link States (Area 1)

Link ID        ADV Router    Age      Seq#          Checksum
10.1.0.1       10.0.40.1      197      0x80000003   0x00582F


          Summary Net Link States (Area 1)

Link ID        ADV Router    Age      Seq#          Checksum
10.0.0.0       10.0.40.1      1280     0x80000002   0x00A952
10.0.1.0       10.0.40.1      1301     0x80000001   0x009666
10.0.20.1      10.0.40.1      1301     0x80000001   0x00BA2E
10.0.40.1      10.0.40.1      1357     0x80000001   0x00D302
10.0.60.1      10.0.40.1      1301     0x80000001   0x0001BF
10.0.123.240   10.0.40.1      1304     0x80000001   0x005005
10.0.123.244   10.0.40.1      1278     0x80000003   0x00ABE2
10.0.123.248   10.0.40.1      1309     0x80000003   0x00612E
10.2.0.0       10.0.40.1      1275     0x80000003   0x008574
10.2.1.0       10.0.40.1      1276     0x80000001   0x008871
10.2.2.0       10.0.40.1      154      0x80000007   0x007181
R-5#

```

**R8 的 OSPF 数据库：**观察得知，Area 2 所有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，。

```

R-8#sh ip ospf da
R-8#sh ip ospf database

        OSPF Router with ID (10.0.80.1) (Process ID 60)

          Router Link States (Area 2)

Link ID        ADV Router    Age      Seq#          Checksum Link cou
10.0.60.1      10.0.60.1      1381     0x80000002   0x00C2C4 1
10.0.80.1      10.0.80.1      246      0x80000007   0x0017F6 3
10.1.70.1      10.1.70.1      242      0x80000005   0x00214A 1


          Net Link States (Area 2)

Link ID        ADV Router    Age      Seq#          Checksum
10.2.0.2       10.0.80.1      1381     0x80000001   0x000D21
10.2.2.1       10.0.80.1      246      0x80000001   0x008F92


          Summary Net Link States (Area 2)

Link ID        ADV Router    Age      Seq#          Checksum
10.0.0.0       10.0.60.1      1377     0x80000002   0x001DCA
10.0.1.0       10.0.60.1      1398     0x80000001   0x000ADE
10.0.20.1      10.0.60.1      1398     0x80000001   0x002EA6
10.0.40.1      10.0.60.1      1398     0x80000001   0x00516F
10.0.60.1      10.0.60.1      1418     0x80000001   0x006A43
10.0.123.240   10.0.60.1      1400     0x80000001   0x00C37D
10.0.123.244   10.0.60.1      1374     0x80000003   0x001F58
10.0.123.248   10.0.60.1      1406     0x80000003   0x00D4A6
10.1.0.0       10.0.60.1      281      0x80000001   0x0009DF
10.1.1.0       10.0.60.1      286      0x80000001   0x0008DE
10.1.2.5       10.0.60.1      286      0x80000001   0x00C021
10.1.2.6       10.0.60.1      287      0x80000001   0x00B62A
10.1.2.7       10.0.60.1      246      0x80000001   0x002F70
10.1.2.8       10.0.60.1      247      0x80000001   0x002579
10.1.50.1      10.0.60.1      288      0x80000001   0x00E0D3
10.1.70.1      10.0.60.1      247      0x80000001   0x0086D9

```

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

```
R7#sh ip ospf database

      OSPF Router with ID (10.1.70.1) (Process ID 60)

      Router Link States (Area 1)

Link ID        ADV Router    Age         Seq#          Checksum Link count
10.0.40.1      10.0.40.1     317        0x8000000A   0x00FDAC 1
10.1.50.1      10.1.50.1     271        0x8000000E   0x00FE63 7
10.1.70.1      10.1.70.1     267        0x80000006   0x009BD5 3
10.3.90.1      10.3.90.1     272        0x80000002   0x0008A2 2

      Net Link States (Area 1)

Link ID        ADV Router    Age         Seq#          Checksum
10.1.0.1       10.0.40.1     317        0x80000003   0x00582F

      Summary Net Link States (Area 1)

Link ID        ADV Router    Age         Seq#          Checksum
10.0.0.0       10.0.40.1     1401       0x80000002   0x00A952
10.0.1.0       10.0.40.1     1422       0x80000001   0x009666
10.0.20.1      10.0.40.1     1422       0x80000001   0x00BA2E
10.0.40.1      10.0.40.1     1478       0x80000001   0x00D302
10.0.60.1      10.0.40.1     1422       0x80000001   0x0001BF
10.0.123.240   10.0.40.1     1423       0x80000001   0x005005
10.0.123.244   10.0.40.1     1397       0x80000003   0x00ABE2
10.0.123.248   10.0.40.1     1429       0x80000003   0x00612E
10.2.0.0       10.0.40.1     1395       0x80000003   0x008574
10.2.1.0       10.0.40.1     1395       0x80000001   0x008871
10.2.2.0       10.0.40.1     273        0x80000007   0x007181

      Router Link States (Area 2)

Link ID        ADV Router    Age         Seq#          Checksum Link count
10.0.60.1      10.0.60.1     1409       0x80000002   0x00C2C4 1
10.0.80.1      10.0.80.1     275        0x80000007   0x0017F6 3
10.1.70.1      10.1.70.1     270        0x80000005   0x00214A 1

      Link ID        ADV Router    Age         Seq#          Checksum
10.2.0.2       10.0.80.1     1411       0x80000001   0x000D21
10.2.2.1       10.0.80.1     277        0x80000001   0x008F92

      Summary Net Link States (Area 2)

Link ID        ADV Router    Age         Seq#          Checksum
10.0.0.0       10.0.60.1     1407       0x80000002   0x001DCA
10.0.1.0       10.0.60.1     1432       0x80000001   0x000ADE
10.0.20.1      10.0.60.1     1432       0x80000001   0x002EA6
10.0.40.1      10.0.60.1     1433       0x80000001   0x00516F
10.0.60.1      10.0.60.1     1453       0x80000001   0x006A43
10.0.123.240   10.0.60.1     1433       0x80000001   0x00C37D
10.0.123.244   10.0.60.1     1407       0x80000003   0x001F5B
10.0.123.248   10.0.60.1     1438       0x80000003   0x00D4A6
10.1.0.0       10.0.60.1     313        0x80000001   0x0009DF
10.1.1.0       10.0.60.1     319        0x80000001   0x0008DE
10.1.2.5       10.0.60.1     319        0x80000001   0x00C021
10.1.2.6       10.0.60.1     319        0x80000001   0x00B62A
10.1.2.7       10.0.60.1     279        0x80000001   0x002F70
10.1.2.8       10.0.60.1     279        0x80000001   0x002579
10.1.50.1      10.0.60.1     319        0x80000001   0x00E0D3
10.1.70.1      10.0.60.1     279        0x80000001   0x0086D9

R7#
```

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。

```
R-8#
R-8#show ip route 10.1.1.3
Routing entry for 10.1.1.0/24
  Known via "ospf 60", distance 110, metric 4, type inter area
  Last update from 10.2.0.1 on FastEthernet0/1, 00:06:19 ago
  Routing Descriptor Blocks:
    * 10.2.0.1, from 10.0.60.1, 00:06:19 ago, via FastEthernet0/1
      Route metric is 4, traffic share count is 1
```

```
R8#sh ip route 10.1.1.0
Routing entry for 10.1.1.0/24
  Known via "ospf 12", distance 110, metric 40, type inter area
  Last update from 10.2.0.1 on FastEthernet0/1, 01:31:46 ago
  Routing Descriptor Blocks:
    * 10.2.0.1, from 10.0.60.1, 01:31:46 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。

```
R-8#
R-8#show ip route 10.1.1.3
% Subnet not in table
R-8#show ip route
```

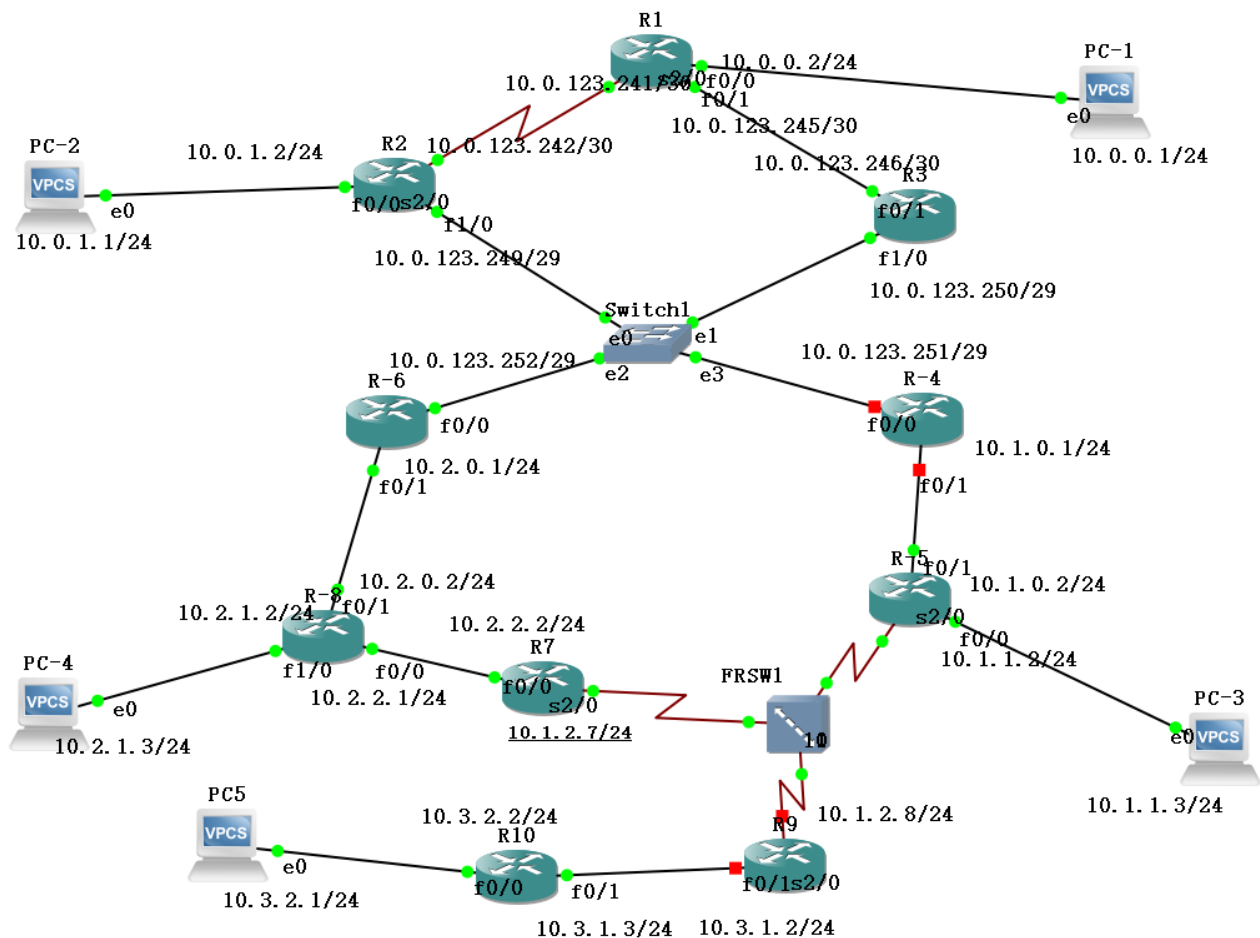
**看看 R7 有没有 PC3 的路由信息：**观察得知，前往子网 10.1.1.0 的路由是存在的，但是由于 Area 2 和 Area

1 不直接交换路由信息，R7 没有向 Area 2 宣告路由的存在。

```
R7#
R7#sh ip route 10.1.1.3
Routing entry for 10.1.1.0/24
  Known via "ospf 60", distance 110, metric 65, type intra area
  Last update from 10.1.2.5 on Serial2/0, 00:14:12 ago
  Routing Descriptor Blocks:
    * 10.1.2.5, from 10.1.50.1, 00:14:12 ago, via Serial2/0
      Route metric is 65, 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。

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:

```
R8(config)#interface f0/1
R8(config-if)# ip addr 10.3.1.3 255.255.255.0
R8(config-if)# no shut
R8(config)#interface f0/0
R8(config-if)# ip addr 10.3.2.2 255.255.255.0
R8(config-if)# no shut
R8(config)#interface loopback 0
R8(config-if)# Ip address 10.3.100.1 255.255.255.252
R8(config)# Router ospf 60
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

```
OSPF Router with ID (10.3.100.1) (Process ID 60)

Router Link States (Area 3)

Link ID          ADV Router      Age      Seq#           Checksum Link count
10.3.90.1        10.3.90.1      89       0x80000002    0x003691 2
10.3.100.1       10.3.100.1     89       0x80000002    0x008DFA 3

Net Link States (Area 3)

Link ID          ADV Router      Age      Seq#           Checksum
10.3.1.2         10.3.90.1      90       0x80000001    0x0038AE
R10#
```

**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#
R10#sh 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 [110/2] via 10.3.1.2, 00:01:37, 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，稍后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 60
R4(config-router)# area 1 virtual-link 10.0.90.1
```

**R9 配置命令：**

```
R9(config)# Router ospf 60
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 FastEthernet0/1 与 R9（RID 是 10.3.90.1）

建立了虚链路，使用的 Cost 值为 65。



```

R-4#
R-4#show ip ospf virtual-links
*Mar 1 00:00:33.103: %OSPF-5-ADJCHG: Process 60, Nbr 10.3.90.1 on OSPF_VL0 from LOADING to FULL, Loading Done
R-4#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 65
  Transmit Delay is 1 sec, State POINT_TO_POINT,
  Timer intervals configured, Hello 10, Dead 40, Wait 40, Retransmit 5
    Hello due in 00:00:06
  Adjacency State FULL (Hello suppressed)
  Index 3/4, retransmission queue length 2, number of retransmission 0
  First 0x64DDB7B0(11)/0x0(0) Next 0x64DDB7B0(11)/0x0(0)
  Last retransmission scan length is 0, maximum is 0
  Last retransmission scan time is 0 msec, maximum is 0 msec
  Link State retransmission due in 2088 msec
R-4#

```

查看 R9 虚链路：观察得知，R9 通过区域 1 的接口 Serial2/0 与 R4（RID 是 10.0.40.1）建立了虚链路，使用的 Cost 值为 65。

```

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 Serial2/0, Cost of using 65
  Transmit Delay is 1 sec, State POINT_TO_POINT,
  Timer intervals configured, Hello 10, Dead 40, Wait 40, Retransmit 5
    Hello due in 00:00:02
  Adjacency State FULL (Hello suppressed)
  Index 1/3, 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
R9#

```

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。

```

R-4#
R-4#show ip ospf neighbor

```

Neighbor ID	Pri	State	Dead Time	Address	Interface
10.0.20.1	1	2WAY/DROTHER	00:00:34	10.0.123.249	FastEthernet0/0
10.0.30.1	1	FULL/DR	00:00:33	10.0.123.250	FastEthernet0/0
10.0.60.1	1	FULL/BDR	00:00:30	10.0.123.252	FastEthernet0/0
10.3.90.1	0	FULL/-	-	10.1.2.8	OSPF_VL0
10.1.50.1	1	FULL/DR	00:00:39	10.1.0.2	FastEthernet0/1

```

R-4#
R-4#

```

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/-	00:01:49	10.1.2.6	Serial2/0
10.3.100.1	1	FULL/DR	00:00:32	10.3.1.3	FastEthernet0/1

```

R9#

```

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, 23 subnets, 4 masks
O IA 10.1.2.8/32 [110/1] via 10.3.1.2, 00:03:09, FastEthernet0/1
C 10.3.1.0/24 is directly connected, FastEthernet0/1
O IA 10.2.0.0/24 [110/68] via 10.3.1.2, 00:02:50, FastEthernet0/1
O IA 10.2.1.0/24 [110/69] via 10.3.1.2, 00:02:50, FastEthernet0/1
O IA 10.2.2.0/24 [110/69] via 10.3.1.2, 00:02:50, FastEthernet0/1
O IA 10.1.1.0/24 [110/66] via 10.3.1.2, 00:03:09, FastEthernet0/1
O IA 10.0.0.0/24 [110/69] via 10.3.1.2, 00:02:51, FastEthernet0/1
C 10.3.2.0/24 is directly connected, FastEthernet0/0
O IA 10.1.0.0/24 [110/66] via 10.3.1.2, 00:03:11, FastEthernet0/1
O IA 10.0.1.0/24 [110/68] via 10.3.1.2, 00:02:51, FastEthernet0/1
O IA 10.1.2.5/32 [110/65] via 10.3.1.2, 00:03:11, FastEthernet0/1
O IA 10.1.2.7/32 [110/129] via 10.3.1.2, 00:03:11, FastEthernet0/1
O IA 10.1.2.6/32 [110/65] via 10.3.1.2, 00:03:13, FastEthernet0/1
O IA 10.0.20.1/32 [110/68] via 10.3.1.2, 00:02:54, FastEthernet0/1
O IA 10.0.40.1/32 [110/67] via 10.3.1.2, 00:02:54, FastEthernet0/1
O IA 10.0.60.1/32 [110/68] via 10.3.1.2, 00:02:54, FastEthernet0/1
O IA 10.1.50.1/32 [110/66] via 10.3.1.2, 00:03:14, FastEthernet0/1
O IA 10.1.70.1/32 [110/130] via 10.3.1.2, 00:03:14, FastEthernet0/1
O 10.3.90.1/32 [110/2] via 10.3.1.2, 00:03:14, FastEthernet0/1
C 10.3.100.0/30 is directly connected, Loopback0
O IA 10.0.123.240/30 [110/131] via 10.3.1.2, 00:02:55, FastEthernet0/1
O IA 10.0.123.244/30 [110/68] via 10.3.1.2, 00:02:56, FastEthernet0/1
O IA 10.0.123.248/29 [110/67] via 10.3.1.2, 00:02:56, FastEthernet0/1
R10#
R10#
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 10.3.90.1 宣告。

```

R10#
R10#sh ip ospf database

        OSPF Router with ID (10.3.100.1) (Process ID 60)

        Router Link States (Area 3)

Link ID      ADV Router   Age         Seq#         Checksum Link
10.3.90.1    10.3.90.1    213        0x80000006  0x00477A  2
10.3.100.1   10.3.100.1   443        0x80000004  0x009FE5  3

        Net Link States (Area 3)

Link ID      ADV Router   Age         Seq#         Checksum
10.3.1.3     10.3.100.1   443        0x80000001  0x00BF1C

        Summary Net Link States (Area 3)

Link ID      ADV Router   Age         Seq#         Checksum
10.0.0.0     10.3.90.1    189        0x80000001  0x00C0C5
10.0.1.0     10.3.90.1    189        0x80000001  0x00ABDA
10.0.20.1    10.3.90.1    189        0x80000001  0x00CFA2
10.0.40.1    10.3.90.1    189        0x80000001  0x00E876
10.0.60.1    10.3.90.1    189        0x80000001  0x001634
10.0.123.240 10.3.90.1    189        0x80000001  0x006579
10.0.123.244 10.3.90.1    189        0x80000001  0x00C455
10.0.123.248 10.3.90.1    191        0x80000001  0x007AA0
10.1.0.0     10.3.90.1    216        0x80000001  0x0096F1
10.1.1.0     10.3.90.1    217        0x80000001  0x008BFB
10.1.2.5     10.3.90.1    217        0x80000001  0x00443E
10.1.2.6     10.3.90.1    217        0x80000001  0x003A47
10.1.2.7     10.3.90.1    217        0x80000001  0x00B28D
10.1.2.8     10.3.90.1    217        0x80000001  0x00A31C
10.1.50.1    10.3.90.1    219        0x80000001  0x0064F0
10.1.70.1    10.3.90.1    220        0x80000001  0x000AF6
10.2.0.0     10.3.90.1    195        0x80000001  0x009EE6
10.2.1.0     10.3.90.1    195        0x80000001  0x009DE5
10.2.2.0     10.3.90.1    195        0x80000001  0x0092EF
R10#
R10#

```

31. 在 R9 上手工合并 Area 0 上的子网路由（命令：area 0 range 10.0.0.0 255.255.0.0，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, 24 subnets, 5 masks
C    10.3.1.0/24 is directly connected, FastEthernet0/1
O IA  10.2.0.0/24 [110/67] via 10.1.2.6, 00:00:35, Serial2/0
O IA  10.2.1.0/24 [110/68] via 10.1.2.6, 00:00:35, Serial2/0
C    10.1.2.0/24 is directly connected, Serial2/0
O IA  10.2.2.0/24 [110/68] via 10.1.2.6, 00:00:35, Serial2/0
O    10.1.1.0/24 [110/65] via 10.1.2.6, 00:00:35, Serial2/0
O    10.0.0.0/24 [110/68] via 10.1.2.6, 00:00:35, Serial2/0
O    10.0.0.0/16 is a summary, 00:00:37, Null0
O    10.3.2.0/24 [110/2] via 10.3.1.3, 00:00:37, FastEthernet0/1
O    10.1.0.0/24 [110/65] via 10.1.2.6, 00:00:37, Serial2/0
O    10.0.1.0/24 [110/67] via 10.1.2.6, 00:00:37, Serial2/0
O    10.1.2.5/32 [110/64] via 10.1.2.6, 00:00:37, Serial2/0
O    10.1.2.7/32 [110/128] via 10.1.2.6, 00:00:38, Serial2/0
O    10.1.2.6/32 [110/64] via 10.1.2.6, 00:00:38, Serial2/0
O    10.0.20.1/32 [110/67] via 10.1.2.6, 00:00:38, Serial2/0
O    10.0.40.1/32 [110/66] via 10.1.2.6, 00:00:39, Serial2/0
O    10.0.60.1/32 [110/67] via 10.1.2.6, 00:00:39, Serial2/0
O    10.1.50.1/32 [110/65] via 10.1.2.6, 00:00:39, Serial2/0
O    10.1.70.1/32 [110/129] via 10.1.2.6, 00:00:39, Serial2/0
C    10.3.90.0/30 is directly connected, Loopback0
O    10.3.100.1/32 [110/2] via 10.3.1.3, 00:00:40, FastEthernet0/1
O    10.0.123.240/30 [110/130] via 10.1.2.6, 00:00:40, Serial2/0
O    10.0.123.244/30 [110/67] via 10.1.2.6, 00:00:40, Serial2/0
O    10.0.123.248/29 [110/66] via 10.1.2.6, 00:00:40, Serial2/0
R9#
R9#
R9#

```

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。

```

Gateway of last resort is not set

10.0.0.0/8 is variably subnetted, 16 subnets, 4 masks
O IA  10.1.2.8/32 [110/1] via 10.3.1.2, 00:05:58, FastEthernet0/1
C    10.3.1.0/24 is directly connected, FastEthernet0/1
O IA  10.2.0.0/24 [110/68] via 10.3.1.2, 00:05:38, FastEthernet0/1
O IA  10.2.1.0/24 [110/69] via 10.3.1.2, 00:05:38, FastEthernet0/1
O IA  10.2.2.0/24 [110/69] via 10.3.1.2, 00:05:38, FastEthernet0/1
O IA  10.1.1.0/24 [110/66] via 10.3.1.2, 00:05:58, FastEthernet0/1
O IA  10.0.0.0/16 [110/67] via 10.3.1.2, 00:00:13, FastEthernet0/1
C    10.3.2.0/24 is directly connected, FastEthernet0/0
O IA  10.1.0.0/24 [110/66] via 10.3.1.2, 00:05:59, FastEthernet0/1
O IA  10.1.2.5/32 [110/65] via 10.3.1.2, 00:05:59, FastEthernet0/1
O IA  10.1.2.7/32 [110/129] via 10.3.1.2, 00:05:59, FastEthernet0/1
O IA  10.1.2.6/32 [110/65] via 10.3.1.2, 00:05:59, FastEthernet0/1
O IA  10.1.50.1/32 [110/66] via 10.3.1.2, 00:06:01, FastEthernet0/1
O IA  10.1.70.1/32 [110/130] via 10.3.1.2, 00:06:01, FastEthernet0/1
O    10.3.90.1/32 [110/2] via 10.3.1.2, 00:06:01, FastEthernet0/1
C    10.3.100.0/30 is directly connected, Loopback0
R10#
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？  
不一定要相同。可以配置多个进程号，但是不同的进程之间是相互独立的，通过不同的进程学习到的路由也不会相互传递。
  
- 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？
  1. 路由器上的最高 IP 地址将成为此路由器的路由器 ID。
  2. 会选择回环接口为 Router ID.
  
- 如果 Router ID 对应的接口 down 了，路由器会自动重新选择另一个接口地址作为新的 Router ID 吗？  
不会。保留原先那个。
  
- 宣告网络属于哪个 area 的命令中，网络地址后面的参数是子网掩码吗？为什么要写成 0.0.255.255，而不是 255.255.0.0？  
不是子网掩码，是通配符掩码(反掩码)。此时为 1 的位标识可以忽略的 ip 地址不同；为 0 不能忽略。
  
- 是不是所有其他 Area 上的路由器都只和 Area 0 上的路由器进行路由信息交换？虚链路的作用是什么？

是。把没有直接物理连接到主干的区域连接到主干区域。

- 为什么要在区域边界路由器上进行路由合并？

当网络较大时可以有效减少路由信息

## 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：

所以为什么要手工指定那个 ospf 进程号呢？

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：

我觉得我路由器 5 的 private 配置文件没写错啊，输进去也好好的，为啥子就有一个端口 s2/0 那玩意一直没办法自动初始化呢？

你对本实验安排有哪些更好的建议呢？欢迎献计献策：感觉 GNS3 好难用....