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

实验名称：动态路由协议 OSPF 配置　　实验类型：　操作实验

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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
- 按照下面的要求分别逐步配置各路由器上的 OSPF 协议，使得各路由器能够互相学习到新的路由信息：
    1. 全部路由器属于同一个 Area 0
    2. 修改部分路由器，使其属于 Area 1
    3. 找出一部分不与 Area 0 上的路由器直接连接的路由器，使其属于 Area 2，通过设置 Virtual Link 使其通过 Area 1 与 Area 0 进行路由信息交换
- 分别在上述三种情况下，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

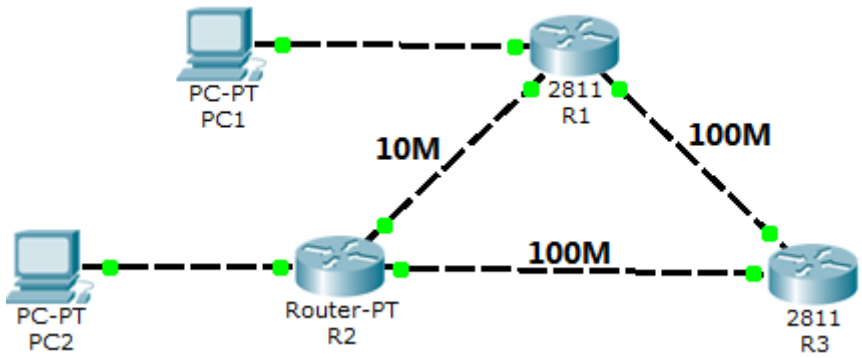
三、 主要仪器设备

- 联网的 PC 机
- PacketTracer 模拟软件

四、 操作方法与实验步骤

Part 1. 单域 OSPF 路由协议配置

- 按照拓扑图连接 PC 和路由器，R1 和 R2 之间采用 Ethernet 接口，其他采用 FastEthernet 或 GigabitEthernet。如果路由器默认只有 2 个物理接口，可以添加模块。



- 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。分配地址时请遵循下面的规则：
  a) PC 和路由器连接的子网使用 10.0.0.0/8 的网络地址进行扩展，每个局域网分别使用 10.0.0.0/16、10.1.0.0/16、10.2.0.0/16 等子网地址。
  b) 路由器与路由器连接的子网使用 192.168.0.0/24 的网络进行扩展，并使用串行掩码，即 30 位长度，每个子网刚好 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）。每个互联的子网分别使用 192.168.0.0/30、192.168.0.128/30、192.168.0.192/30、192.168.0.224/30 等子网地址，例如 R1-R3 的 IP 地址分别为 192.168.0.1/30、192.168.0.2/30; R2-R3 的 IP 地址分别为 192.168.0.129/30、192.168.0.130/30。
- 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
- 给某个路由器的回环接口配置地址
  a) Router(config)# interface loopback 0
  b) Router(config-if)# ip address < ip> <mask>
- 去除路由器内的静态路由设置和其他 的动态路由协议设置（如果有）

  Router(config)# no router rip

Router(config)# no ip route <ip_net> <mask> <next_hop>

- 在各路由器上激活 OSPF 协议（进程号设置为学号后 2 位）

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

- 宣告各路由器各端口所属子网的区域 ID（全部为 0）

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

- 观察各路由器的 OSPF 学习到的拓扑数据，看是否与实际相符，并注意观察路由器选择了哪个地址作为 Router ID

  Router# show ip ospf database

  手工指定 Router ID 的命令:

  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，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

  Router# show ip ospf neighbor detail

- 观察路由器的 OSPF 接口状态，记录 cost 值

  Router# show ip ospf interface

- 观察各路由器的路由表，特别是 R1 会选择哪条路由到达 PC2 所在的网络
- 通过 Ping 检查各 PC2 之间的联通性
- 使用 debug 命令实时显示路由器之间交换的路由信息事件

  Router# debug ip ospf events

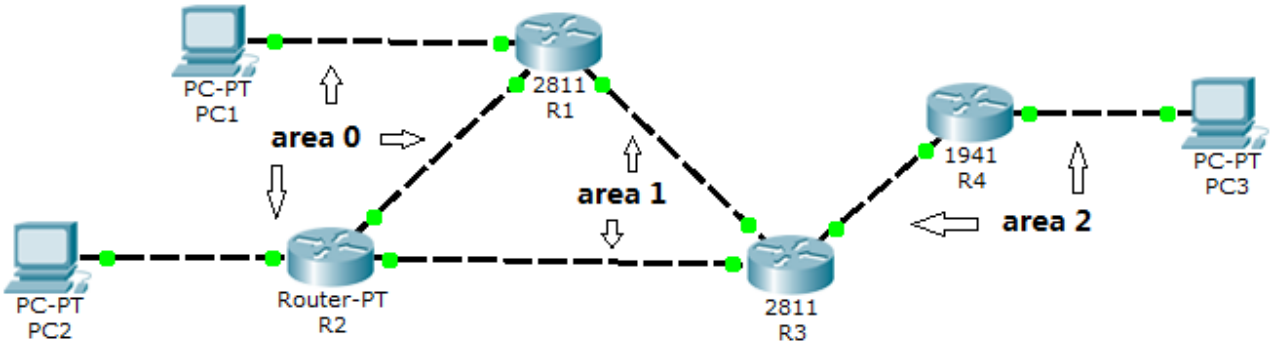
  观察完毕后，可以关闭调试信息显示：

  Router# no debug ip ospf events

- 断开 R2 和 R3 的网络连接，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

Part 2. 多域 OSPF 路由协议配置

- 在第一部分的基础上，增加一台路由器和 PC 机，如图所示连接



- 按图重新宣告各路由器直连网络所属的 Area，也就是把 R1-R3、R2-R3 之间的子网宣告成属于 Area 1，把 R3-R4 之间的子网宣告成属于 Area 2。
- 使用 172.16.0.0/16 的子网进行扩展，给路由器 R4 的各接口配置 IP 地址。例如给 R3-R4 的子网分配 172.16.0.0/24 的地址，给 R4-PC3 的子网分配 172.16.1.0/24 的地址。
- 在路由器 R4 上启用 OSPF 路由协议，宣告 R4 所有接口的子网都属于 Area 2。
- 给 PC3 配置 IP 地址，并设置默认网关为 R4
- 测试各 PC 间的联通性，特别是 PC3 与其他 PC 间的联通性（不通的原因是什么？）
- 由于 Area 2 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 R3 和 R1 之间为 Area 2 建立一个虚链路，<area-id>填写 1（Area 1 为用于传递数据的区域），<router ID>分别设为对方的 Router ID

  Router(config-router)# area <area-id> virtual-link <router ID>
- 等待一会儿后，再次测试 PC3 与其他 PC 间的联通性
- 查看各路由器中的路由表，特别是 R3、R4 是否对 Area 0 中的网络地址进行了自动合并，也可以在区域边界路由器 R3 上手工进行合并：

  Router(config-router)# area <area-id> range <ip_net> <mask>
- 查看各路由器中 OSPF 的数据和状态

  Router# show ip ospf database

  Router# show ip ospf neighbor detail
- 使用 debug 跟踪不同 Area 之间路由器是否会交换路由信息

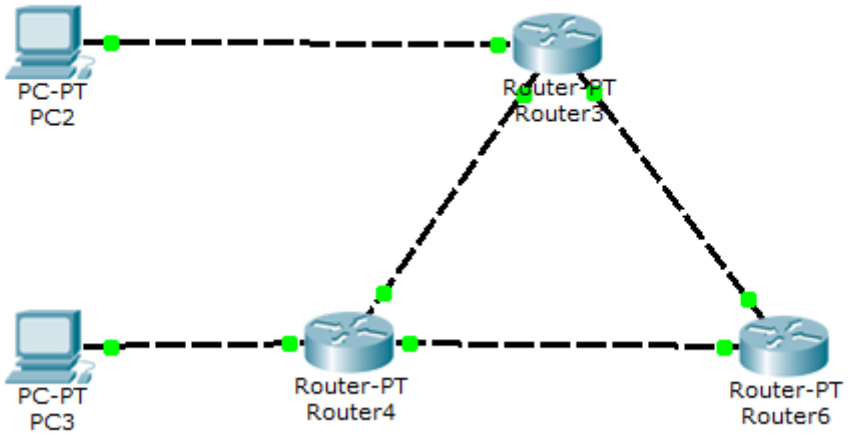
五、 实验数据记录和处理

以下实验记录均需结合屏幕截图（截取输入的命令和运行结果），进行文字标注（看完请删除本句）。

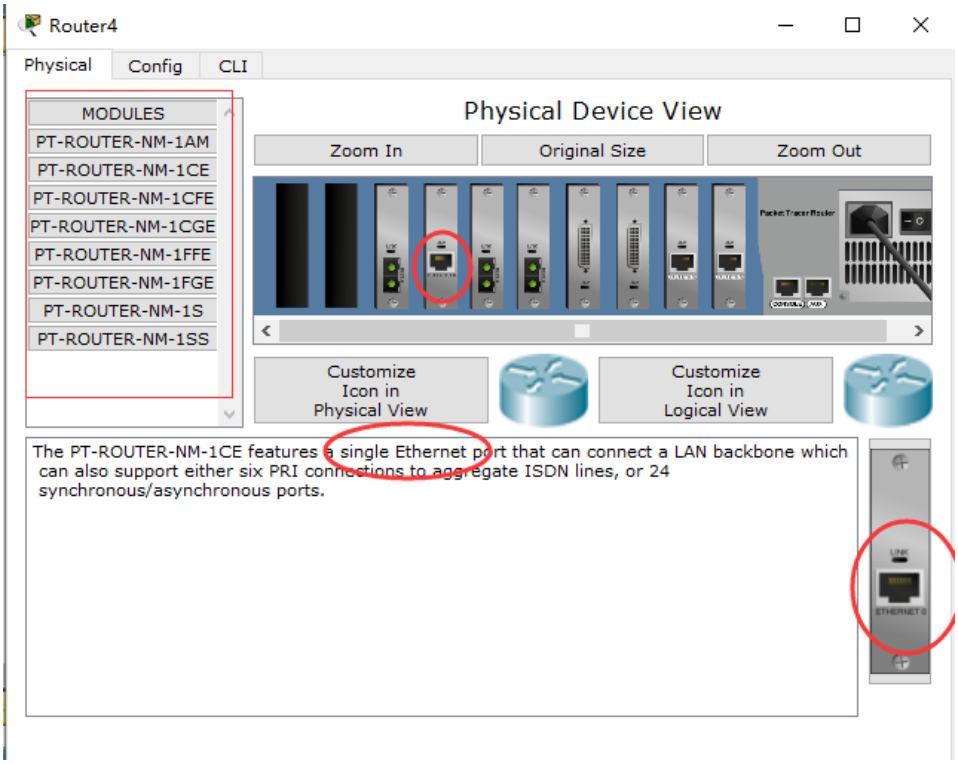
----Part 1. 单域 OSPF 路由协议配置-----

- 激活路由器 R1 各接口，并配置 IP 地址（如端口不够，可以添加模块）。配置 PC1 的 IP 地址和默认网关。根据需要降低 R1 和 R2 之间的接口带宽为 10M。

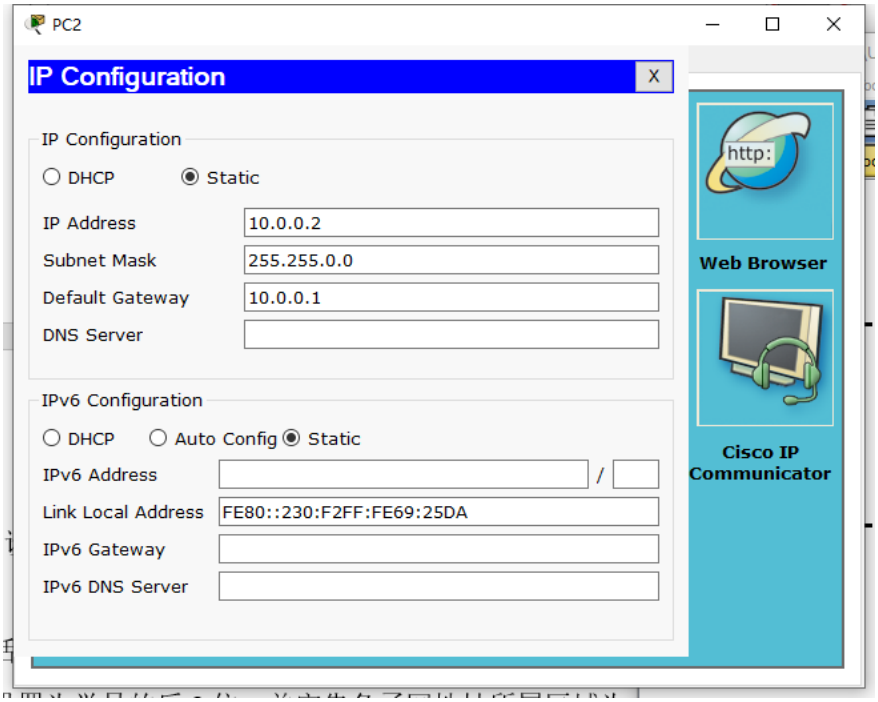
如图，添加三个通用路由器和两台 PC 机，将 R3 和 R4 使用 Ethernet 进行连接，将其他端口使用 FastEthernet 进行连接（如图是已经配置好 IP 的情况）。



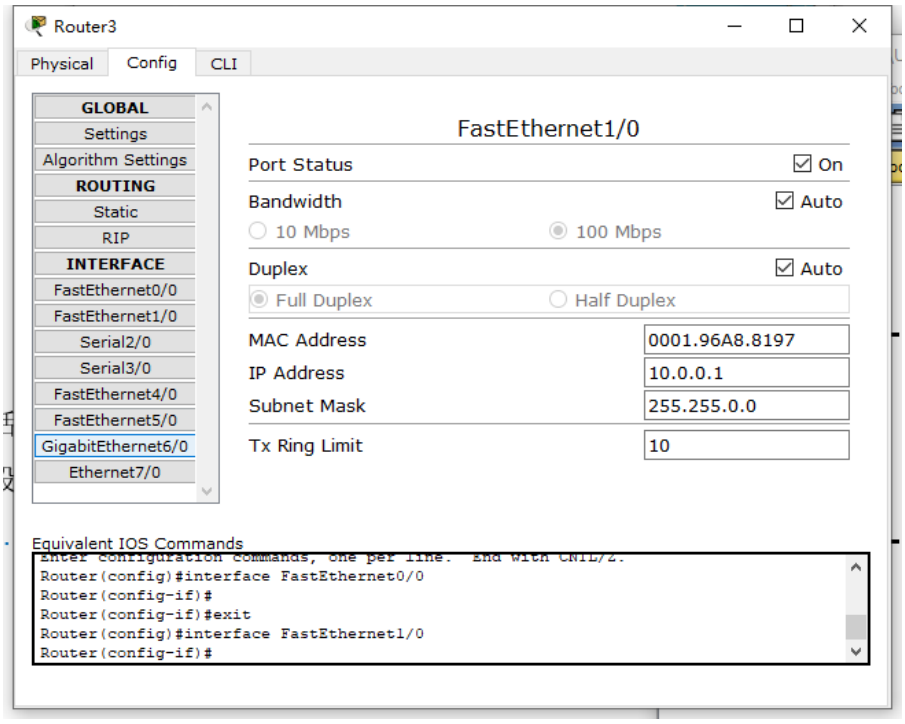
配置普通 Ethernet 的方法是在路由器中添加对应的拓展模块，如图：



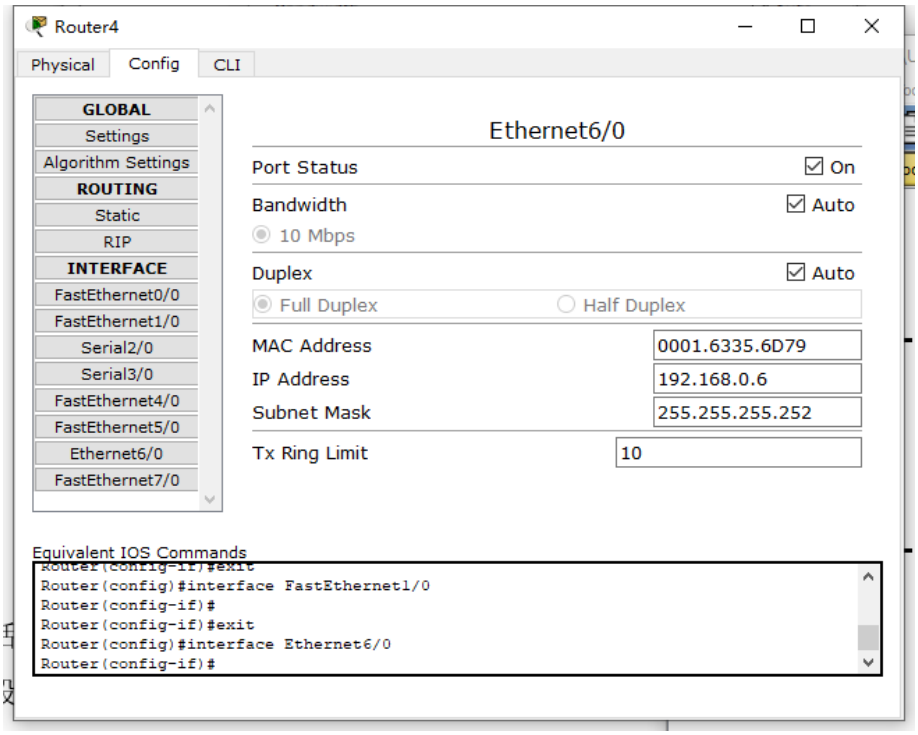
连接好设备后配置对应接口的 IP 地址：



（例子：PC2）

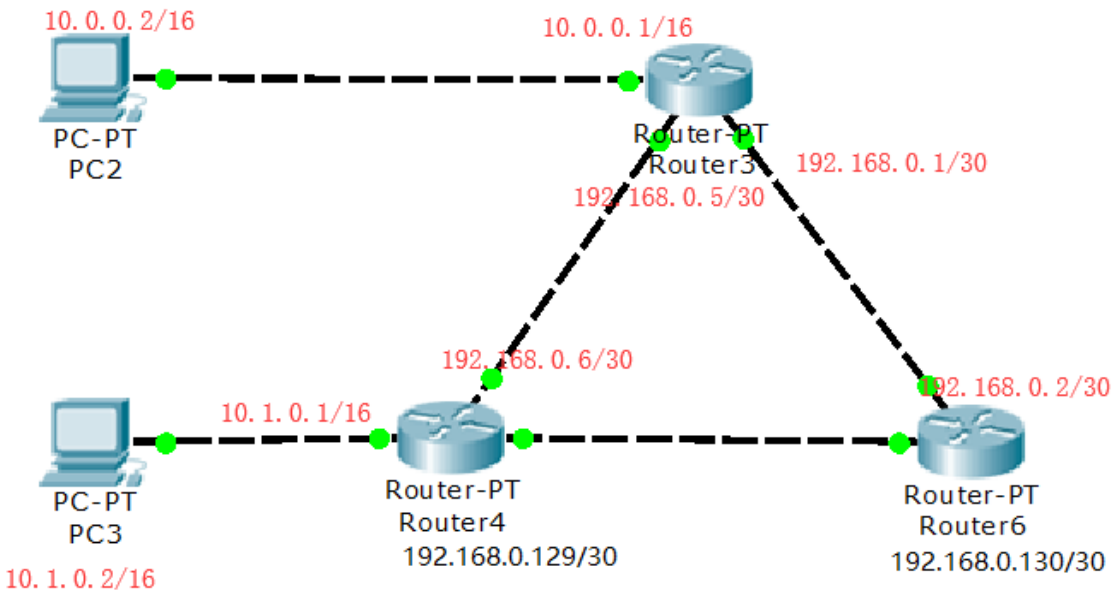


（例子：路由器 3 连接 PC2 的端口）



（例子：路由器 4 和 3 连接的端口配置）

最终各连线上的 IP 地址配置如下：



由于网络带宽已经依照连接方式自动配置（10M 和 100M），我们不需要再调整。

测试连接：

```
PC>ping 10.0.0.1

Pinging 10.0.0.1 with 32 bytes of data:

Reply from 10.0.0.1: bytes=32 time=0ms TTL=255
Reply from 10.0.0.1: bytes=32 time=0ms TTL=255
Reply from 10.0.0.1: bytes=32 time=0ms TTL=255
Reply from 10.0.0.1: bytes=32 time=0ms TTL=255

Ping statistics for 10.0.0.1:
    Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),
Approximate round trip times in milli-seconds:
    Minimum = 0ms, Maximum = 0ms, Average = 0ms
```

（PC2 ping 路由器 3）

```
Pinging 10.1.0.1 with 32 bytes of data:

Reply from 10.1.0.1: bytes=32 time=0ms TTL=255
Reply from 10.1.0.1: bytes=32 time=0ms TTL=255
Reply from 10.1.0.1: bytes=32 time=0ms TTL=255
Reply from 10.1.0.1: bytes=32 time=0ms TTL=255

Ping statistics for 10.1.0.1:
    Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),
Approximate round trip times in milli-seconds:
    Minimum = 0ms, Maximum = 0ms, Average = 0ms

PC>
```

（PC3 ping 路由器 4）

```
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.0.6, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 0/2/8 ms


Router>ping 192.168.0.5

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.0.5, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 0/1/5 ms
```

（路由器 34 互 ping 成功）

另测试其他路由器的连接情况，均成功 ping 通，此处限于篇幅不再截图。上述实验结果证明我们已经成功按照要求搭建了网络拓扑。

- 激活路由器 R1 的 OSPF 动态路由协议（命令：router ospf 进程 ID），其中进程 ID 请设置为学号的后 2 位。并宣告各子网地址所属区域为 Area 0（命令：network A.B.0.0 0.0.255.255 area 0）。

将 R3（例子中 R1 位置）的 OSPF 动态路由协议激活，进程 ID 设置为 34：

```
Router#config
Configuring from terminal, memory, or network [terminal]?
Enter configuration commands, one per line.  End with CNTI
Router(config)#route ospf 34
Router(config-router)#
```

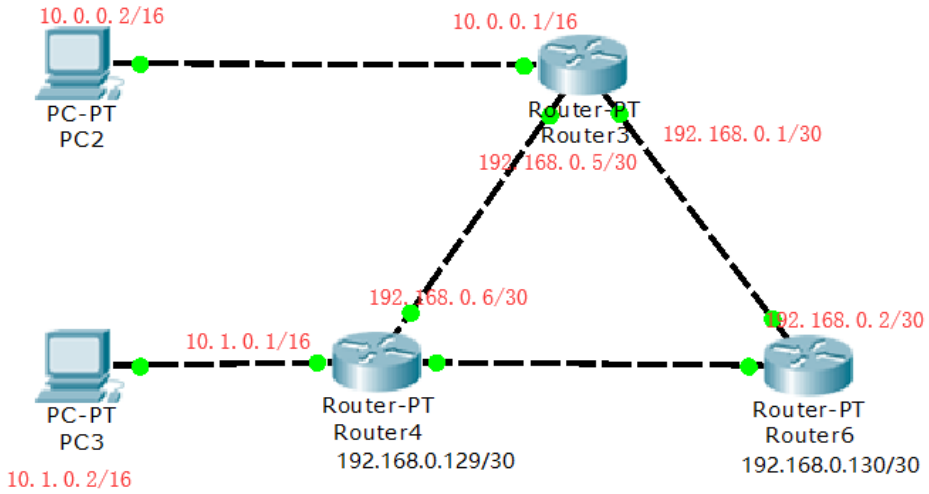
宣告各子网地址所属区域为 Area 0 后使用 write 命令保存设置：

```
Router#config
Configuring from terminal, memory, or network [terminal]?
Enter configuration commands, one per line.  End with CNTL/Z.
Router(config)#router ospf 34
Router(config-router)#network 192.168.0.0 0.0.0.255 area 0
Router(config-router)#network 192.168.0.4 0.0.0.255 area 0
Router(config-router)#network 10.0.0.0 0.0.0.255 area 0
Router(config-router)#end
Router#
%SYS-5-CONFIG_I: Configured from console by console

Router#write
Building configuration...
[OK]
```

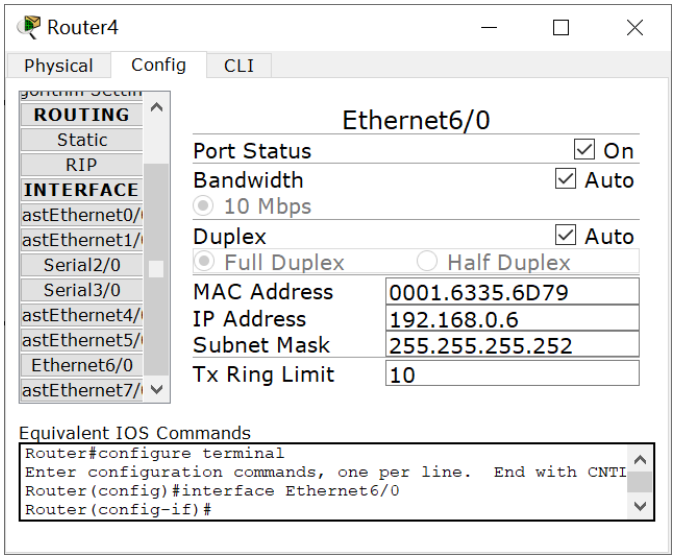
【后期校对注：这里我不小心把 0.0.255.255 输成了 0.0.0.255，且这一错误影响了第二部分实验，因此在第二部分前我重新做了修改，不过这一错误没有影响第一部分实验。】

- 激活路由器 R2 各接口，并配置 IP 地址。配置 PC2 的 IP 地址和默认网关。根据需要降低 R1 和 R2 之间的接口带宽为 10M。

  如图，在第一题中我们已经完成了配置：



此外，由于网络带宽已经依照连接方式自动配置（10M，如图），我们不需要再调整。



（可以看到 Bandwidth 已经被设定为 10Mbps）

- 激活路由器 R2 的 OSPF 动态路由协议（命令：router ospf 进程 ID），其中进程 ID 请设置为学号的后 2 位。先手工指定 Router ID（命令：router-id x.x.x.x），然后宣告各子网地址所属区域为 Area 0。

  同第 2 题，输入以下命令激活 R4（例子中 R2）的的 OSPF 动态路由协议，并在此前手工指定 router ID：

```
outer(config)#router ospf 34
outer(config-router)#router-id 192.168.0.5
outer(config-router)#Reload or use "clear ip ospf process" command, for this to
 take effect


outer(config-router)#router-id 192.168.0.130
outer(config-router)#Reload or use "clear ip ospf process" command, for this to
 take effect

outer(config-router)#network 192.168.0.128 0.0.0.255 area 0
outer(config-router)#network 192.168.0.4 0.0.0.255 area 0
outer(config-router)#network 10.1.0.0 0.0.0.255 area 0
outer(config-router)#end
outer#
SYS-5-CONFIG_I: Configured from console by console

outer#write
uilding configuration...
OK]
outer#clear ip ospf process
eset ALL OSPF processes? [no]: yes
```

- 激活路由器 R3 各接口，并配置 IP 地址。同时也给路由器 R3 回环接口配置 IP 地址（命令：interface loopback 0， ip address A.B.C.D x.x.x.x）

  在第一题中我们已经完成了各接口的激活与配置，这里仅运行以下命令为 R6(R3)回环接口配置 IP 地址：

```
Router>en
Router#config
Configuring from terminal, memory, or network [terminal]?
Enter configuration commands, one per line.  End with CNTL/Z.
Router(config)#interface loopback 0

Router(config-if)#
%LINK-5-CHANGED: Interface Loopback0, changed state to up

%LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback0, changed state to up

Router(config-if)#ip address 127.0.0.1 x.x.x.x
                                       ^
% Invalid input detected at '^' marker.

Router(config-if)#ip address 127.0.0.1 255.255.255.255
Not a valid host address - 127.0.0.1
Router(config-if)#ip address 192.168.0.9 255.255.255.255
Router(config-if)#end
Router#
%SYS-5-CONFIG_I: Configured from console by console

Router#write
Building configuration...
[OK]
Router#
```

（配置环回地址的过程）

如图，将 192.168.0.9 配置为 R6（R3）的环回地址，子网掩码为 255.255.255.255，保存设置。配置完成后测试该环回地址：

```
Router#ping 192.168.0.9

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.0.9, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 0/7/18 ms
```

发现可以成功 ping 通，且速度极快，可初步确定环回地址配置成功。

【后期校对注：这里我没理解 x.x.x.x 的意义，把 R3 的环路地址配成了这个，不过没有影响第一部分实验，第二部分重构拓扑时我进行了纠正，将 R3 的环路地址（包括 Router ID）重新设置为了 **4.4.4.4**。这里我使用错配的实验截图，以体现实验探究的过程】

- 激活路由器 R3 的 OSPF 动态路由协议（命令：router ospf 进程 ID），其中进程 ID 请设置为学号的后 2 位。并设置各子网地址（包括回环接口地址）所属区域为 Area 0。输入如下命令，激活 OSPF 动态路由协议：

  （注：截图中我将子网的反掩码配置错误了，后面做实验二时已经纠正）

```
Router(config)#router ospf 34
Router(config-router)#network 192.168.0.9 0.0.0.255
% Incomplete command.
Router(config-router)#network 192.168.0.9 0.0.0.255 area 0
Router(config-router)#network 192.168.0.1 0.0.0.255 area 0
02:43:11: %OSPF-5-ADJCHG: Process 34, Nbr 192.168.0.130 on FastEthernet1/0 from
LOADING to FULL, Loading Don
02:43:16: %OSPF-5-ADJCHG: Process 34, Nbr 192.168.0.5 on FastEthernet0/0 from LO
ADING to FULL, Loading Done
Router(config-router)#network 192.168.0.129 0.0.0.255 area 0
Router(config-router)#network 192.168.0.129 0.0.0.255 area 0
                          ^
% Invalid input detected at '^' marker.

Router(config-router)#n129etwork 192.168.0. 0.0.0.255 area 0
                     ^
% Invalid input detected at '^' marker.

Router(config-router)#network 192.168.0. 0.0.0.255 area 0
                          ^
% Invalid input detected at '^' marker.

Router(config-router)#network 192.168.0.129 0.0.0.255 area 0
Router(config-router)#network 192.168.0.1 0.0.0.255 area 0
Router(config-router)#end
Router#
%SYS-5-CONFIG_I: Configured from console by console

Router#write
Building configuration...
[OK]
Router#
```

- 分别在各路由器上显示 OSPF 的拓扑数据（命令：show ip ospf database），标记各路由器使用的 Router ID 是多少（来自哪一个接口地址）。

R1（在本题中为 R3）：

```
Router>show ip ospf database
            OSPF Router with ID (192.168.0.5) (Process ID 34)

                Router Link States (Area 0)

Link ID         ADV Router      Age         Seq#       Checksum Link count
192.168.0.130   192.168.0.130   487         0x8000000a 0x002763 3
192.168.0.5     192.168.0.5     481         0x80000009 0x00bace 3
192.168.0.9     192.168.0.9     481         0x80000005 0x0045e6 3

                Net Link States (Area 0)
Link ID         ADV Router      Age         Seq#       Checksum
192.168.0.6     192.168.0.130   1504        0x80000004 0x00e513
192.168.0.129   192.168.0.130   487         0x80000005 0x00a9d7
192.168.0.1     192.168.0.5     481         0x80000003 0x00b492
```

R1（R3）使用自动配置的 192.168.0.5 作为 router ID。

R2（在本题中为 R4）：

```
Router#show ip ospf database
            OSPF Router with ID (192.168.0.130) (Process ID 34)

                Router Link States (Area 0)

Link ID         ADV Router      Age         Seq#       Checksum Link count
192.168.0.130   192.168.0.130   578         0x8000000a 0x002763 3
192.168.0.5     192.168.0.5     572         0x80000009 0x00bace 3
192.168.0.9     192.168.0.9     572         0x80000005 0x0045e6 3

                Net Link States (Area 0)
Link ID         ADV Router      Age         Seq#       Checksum
192.168.0.6     192.168.0.130   1595        0x80000004 0x00e513
192.168.0.129   192.168.0.130   578         0x80000005 0x00a9d7
192.168.0.1     192.168.0.5     572         0x80000003 0x00b492
```

发现之前我们因为错误的理解把 R2 的 Router ID 手动设置错了（R2 没有这个 IP），故重新设置为 129 结尾的 IP 正确结果如下：

```
Router#show ip ospf database
            OSPF Router with ID (192.168.0.129) (Process ID 34)

                Router Link States (Area 0)

Link ID         ADV Router      Age         Seq#       Checksum Link count
192.168.0.5     192.168.0.5     254         0x8000000b 0x00c0c5 3
192.168.1.129   192.168.1.129   553         0x8000000b 0x00e6a2 3
192.168.0.9     192.168.0.9     254         0x8000000a 0x00968f 3
192.168.0.129   192.168.0.129   254         0x8000000f 0x00f096 3

                Net Link States (Area 0)
Link ID         ADV Router      Age         Seq#       Checksum
192.168.0.2     192.168.0.9     616         0x80000002 0x007d1f
192.168.0.6     192.168.0.129   254         0x80000006 0x005ea3
192.168.0.129   192.168.0.129   254         0x80000006 0x00b602
Router#
```

R2(R4)使用基于手动配置的 192.168.0.129 作为 router ID.

R3（在本题中为 R6）:

```
Router>show ip ospf database
            OSPF Router with ID (192.168.0.9) (Process ID 34)

                Router Link States (Area 0)

Link ID         ADV Router      Age         Seq#       Checksum Link count
192.168.0.130   192.168.0.130   935         0x8000000a 0x002763 3
192.168.0.9     192.168.0.9     930         0x80000005 0x0045e6 3
192.168.0.5     192.168.0.5     930         0x80000009 0x00bace 3

                Net Link States (Area 0)
Link ID         ADV Router      Age         Seq#       Checksum
192.168.0.129   192.168.0.130   935         0x80000005 0x00a9d7
192.168.0.1     192.168.0.5     930         0x80000003 0x00b492
192.168.0.6     192.168.0.130   152         0x80000006 0x00b4f8
```

R3 使用自动配置的环路地址作为默认 route-id.

【后期校对注：同上，这里我没理解 x.x.x.x 的意义，把 R3 的环路地址配成了这个，不过没有影响第一部分实验，第二部分重构拓扑时我进行了纠正，将 R3 的环路地址（包括 Router ID）重新设置为了 **4.4.4.4**。这里我使用错配的实验截图，以体现实验探究的过程】

- 分别在各路由器上显示 OSPF 接口数据（命令：show ip ospf interface），标记各路由器各接口的 cost 值是多少。

R1:

```
Router#show ip ospf interface
FastEthernet0/0 is up, line protocol is up
  Internet address is 192.168.0.1/30, Area 0
  Process ID 34, Router ID 192.168.0.5, Network Type BROADCAST, Cost: 1
  Transmit Delay is 1 sec, State BDR, Priority 1
  Designated Router (ID) 192.168.0.9, Interface address 192.168.0.2
  Backup Designated Router (ID) 192.168.0.5, Interface address 192.168.0.1
  Timer intervals configured, Hello 10, Dead 40, Wait 40, Retransmit 5
    Hello due in 00:00:06
  Index 1/1, 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 192.168.0.9  (Designated Router)
  Suppress hello for 0 neighbor(s)
Ethernet7/0 is up, line protocol is up
  Internet address is 192.168.0.5/30, Area 0
  Process ID 34, Router ID 192.168.0.5, Network Type BROADCAST, Cost: 10
  Transmit Delay is 1 sec, State BDR, Priority 1
  Designated Router (ID) 192.168.1.129, Interface address 192.168.0.6
  Backup Designated Router (ID) 192.168.0.5, Interface address 192.168.0.5
  Timer intervals configured, Hello 10, Dead 40, Wait 40, Retransmit 5
    Hello due in 00:00:05
  Index 2/2, flood queue length 0
  Next 0x0(0)/0x0(0)
  Last flood scan length is 1, maximum is 1
  Last flood scan time is 0 msec, maximum is 0 msec
  Neighbor Count is 1, Adjacent neighbor count is 1
    Adjacent with neighbor 192.168.0.129
  Suppress hello for 0 neighbor(s)
FastEthernet1/0 is up, line protocol is up
  Internet address is 10.0.0.1/16, Area 0
  Process ID 34, Router ID 192.168.0.5, Network Type BROADCAST, Cost: 1
  Transmit Delay is 1 sec, State DR, Priority 1
  Designated Router (ID) 192.168.0.5, Interface address 10.0.0.1
  No backup designated router on this network
  Timer intervals configured, Hello 10, Dead 40, Wait 40, Retransmit 5
    Hello due in 00:00:06
  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 0, Adjacent neighbor count is 0
  Suppress hello for 0 neighbor(s)
```

R2:

```
Router>en
Router#show ip ospf interface
FastEthernet0/0 is up, line protocol is up
  Internet address is 10.1.0.1/16, Area 0
  Process ID 34, Router ID 192.168.0.129, Network Type BROADCAST, Cost: 1
  Transmit Delay is 1 sec, State DR, Priority 1
  Designated Router (ID) 192.168.0.129, Interface address 10.1.0.1
  No backup designated router on this network
  Timer intervals configured, Hello 10, Dead 40, Wait 40, Retransmit 5
    Hello due in 00:00:05
  Index 1/1, 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 0, Adjacent neighbor count is 0
  Suppress hello for 0 neighbor(s)
FastEthernet1/0 is up, line protocol is up
  Internet address is 192.168.0.129/30, Area 0
  Process ID 34, Router ID 192.168.0.129, Network Type BROADCAST, Cost: 1
  Transmit Delay is 1 sec, State DR, Priority 1
  Designated Router (ID) 192.168.0.129, Interface address 192.168.0.129
  No backup designated router on this network
  Timer intervals configured, Hello 10, Dead 40, Wait 40, Retransmit 5
    Hello due in 00:00:05
  Index 2/2, flood queue length 0
  Next 0x0(0)/0x0(0)
  Last flood scan length is 1, maximum is 1
  Last flood scan time is 0 msec, maximum is 0 msec
  Neighbor Count is 1, Adjacent neighbor count is 1
    Adjacent with neighbor 192.168.0.9
  Suppress hello for 0 neighbor(s)
Ethernet6/0 is up, line protocol is up
  Internet address is 192.168.0.6/30, Area 0
  Process ID 34, Router ID 192.168.0.129, Network Type BROADCAST, Cost: 10
  Transmit Delay is 1 sec, State DR, Priority 1
  Designated Router (ID) 192.168.0.129, Interface address 192.168.0.6
  No backup designated router on this network
  Timer intervals configured, Hello 10, Dead 40, Wait 40, Retransmit 5
    Hello due in 00:00:04
  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 192.168.0.5
  Suppress hello for 0 neighbor(s)
```

R3:

```
Router#show ip ospf interface
Loopback0 is up, line protocol is up
  Internet address is 192.168.0.9/32, Area 0
  Process ID 34, Router ID 192.168.0.9, Network Type LOOPBACK, Cost: 1
  Loopback interface is treated as a stub Host
FastEthernet0/0 is up, line protocol is up
  Internet address is 192.168.0.2/30, Area 0
  Process ID 34, Router ID 192.168.0.9, Network Type BROADCAST, Cost: 1
  Transmit Delay is 1 sec, State DR, Priority 1
  Designated Router (ID) 192.168.0.9, Interface address 192.168.0.2
  Backup Designated Router (ID) 192.168.0.5, Interface address 192.168.0.1
  Timer intervals configured, Hello 10, Dead 40, Wait 40, Retransmit 5
    Hello due in 00:00:07
  Index 2/2, flood queue length 0
  Next 0x0(0)/0x0(0)
  Last flood scan length is 1, maximum is 1
  Last flood scan time is 0 msec, maximum is 0 msec
  Neighbor Count is 1, Adjacent neighbor count is 1
    Adjacent with neighbor 192.168.0.5  (Backup Designated Router)
  Suppress hello for 0 neighbor(s)
FastEthernet1/0 is up, line protocol is up
  Internet address is 192.168.0.130/30, Area 0
  Process ID 34, Router ID 192.168.0.9, Network Type BROADCAST, Cost: 1
  Transmit Delay is 1 sec, State BDR, Priority 1
  Designated Router (ID) 192.168.1.129, Interface address 192.168.0.129
  Backup Designated Router (ID) 192.168.0.9, Interface address 192.168.0.130
  Timer intervals configured, Hello 10, Dead 40, Wait 40, Retransmit 5
    Hello due in 00:00:07
  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 192.168.0.129
  Suppress hello for 0 neighbor(s)
```

- 分别在各路由器上显示 OSPF 邻居信息（命令：show ip ospf neighbor detail），标记邻居的 Router ID、谁是 DR、谁是 BDR。

R1:

```
Router>en
Router#show ip ospf neighbor detail
 Neighbor 192.168.0.129, interface address 192.168.0.6
    In the area 0 via interface Ethernet7/0
    Neighbor priority is 1, State is FULL, 12 state changes
    DR is 192.168.0.6 BDR is 0.0.0.0
    Options is 0x00
    Dead timer due in 00:00:33
    Neighbor is up for 01:19:48
    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 192.168.0.9, interface address 192.168.0.2
    In the area 0 via interface FastEthernet0/0
    Neighbor priority is 1, State is FULL, 6 state changes
    DR is 192.168.0.2 BDR is 192.168.0.1
    Options is 0x00
    Dead timer due in 00:00:33
    Neighbor is up for 01:19:48
    Index 2/2, retransmission queue length 0, number of retransmission 0
    First 0x0(0)/0x0(0) Next 0x0(0)/0x0(0)
    Last retransmission scan length is 0, maximum is 3
    Last retransmission scan time is 0 msec, maximum is 0 msec
```

R2:

```
Router>show ip ospf neighbor detail
 Neighbor 192.168.0.9, interface address 192.168.0.130
    In the area 0 via interface FastEthernet1/0
    Neighbor priority is 1, State is FULL, 6 state changes
    DR is 192.168.0.129 BDR is 192.168.0.130
    Options is 0x00
    Dead timer due in 00:00:33
    Neighbor is up for 00:49:27
    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 1
    Last retransmission scan time is 0 msec, maximum is 0 msec
 Neighbor 192.168.0.5, interface address 192.168.0.5
    In the area 0 via interface Ethernet6/0
    Neighbor priority is 1, State is FULL, 6 state changes
    DR is 192.168.0.6 BDR is 192.168.0.5
    Options is 0x00
    Dead timer due in 00:00:33
    Neighbor is up for 00:49:27
    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
```

R3:

```
Router>show ip ospf neighbor detail
 Neighbor 192.168.0.5, interface address 192.168.0.1
    In the area 0 via interface FastEthernet0/0
    Neighbor priority is 1, State is FULL, 5 state changes
    DR is 192.168.0.2 BDR is 192.168.0.1
    Options is 0x00
    Dead timer due in 00:00:37
    Neighbor is up for 01:27:15
    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 1
    Last retransmission scan time is 0 msec, maximum is 0 msec
 Neighbor 192.168.0.129, interface address 192.168.0.129
    In the area 0 via interface FastEthernet1/0
    Neighbor priority is 1, State is FULL, 12 state changes
    DR is 192.168.0.129 BDR is 0.0.0.0
    Options is 0x00
    Dead timer due in 00:00:36
    Neighbor is up for 01:27:15
    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 1
    Last retransmission scan time is 0 msec, maximum is 0 msec
```

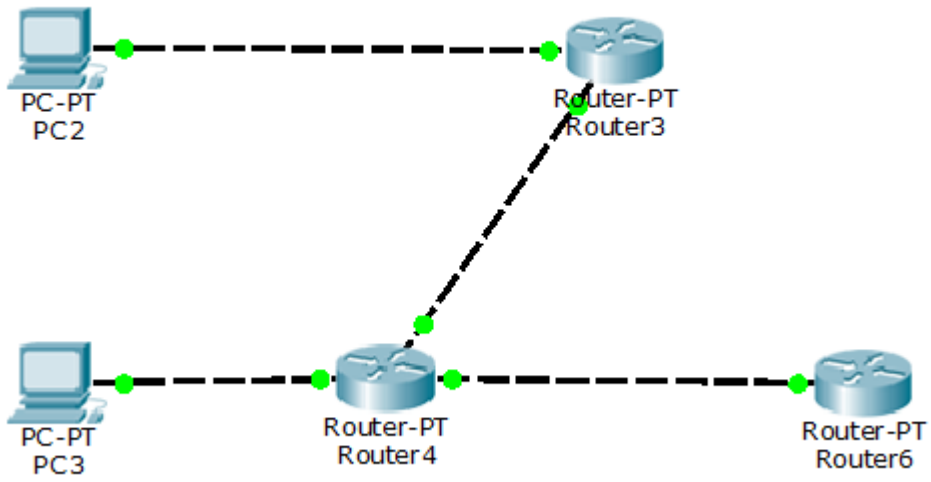
- 显示 R1 的路由表（命令：show ip route），标记到达 PC2 所在子网的下一跳

```
Router#show ip route
Codes: C - connected, S - static, I - IGRP, 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, E - EGP
       i - IS-IS, 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

     10.0.0.0/16 is subnetted, 2 subnets
C       10.0.0.0 is directly connected, FastEthernet1/0
O       10.1.0.0 [110/3] via 192.168.0.2, 00:00:14, FastEthernet0/0
     192.168.0.0/24 is variably subnetted, 4 subnets, 2 masks
C       192.168.0.0/30 is directly connected, FastEthernet0/0
C       192.168.0.4/30 is directly connected, Ethernet7/0
O       192.168.0.9/32 [110/2] via 192.168.0.2, 00:00:14, FastEthernet0/0
O       192.168.0.128/30 [110/2] via 192.168.0.2, 00:00:14, FastEthernet0/0
Router#
```

如图，去往 10.1.0.0 子网的下一跳为 192.168.0.2. 而 192.168.0.2 是属于 R3（本题中 R6）的 IP 地址。

- 断开 R1 和 R3 的接口，再次显示 R1 的路由表，标记到达 PC2 所在子网的下一跳。同时观察 R1 和 R3 两个路由器上的 Router ID 是否发生变化

  首先断开 R1 和 R3 的接口：



等待一段时间后，再次显示 R1 的路由表

```
Router>show ip route
Codes: C - connected, S - static, I - IGRP, 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, E - EGP
       i - IS-IS, 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

     10.0.0.0/16 is subnetted, 2 subnets
C       10.0.0.0 is directly connected, FastEthernet1/0
O       10.1.0.0 [110/11] via 192.168.0.6, 00:00:57, Ethernet7/0
     192.168.0.0/24 is variably subnetted, 3 subnets, 2 masks
C       192.168.0.4/30 is directly connected, Ethernet7/0
O       192.168.0.9/32 [110/12] via 192.168.0.6, 00:00:57, Ethernet7/0
O       192.168.0.128/30 [110/11] via 192.168.0.6, 00:00:57, Ethernet7/0
```

发现 PC2 所在子网的下一跳变成了 192.168.0.6，而 192.168.0.6 是属于 R2（本例中的 R4 的 IP 地址）。说明原先存在的连接断开后，路由表发生了变化。此时检查两者的 route id：

```
Router>show ip ospf database
            OSPF Router with ID (192.168.0.9) (Process ID 34)

                Router Link States (Area 0)

Link ID         ADV Router      Age         Seq#       Checksum Link count
192.168.0.9     192.168.0.9     1096        0x80000006 0x00f818 2
192.168.0.5     192.168.0.5     1096        0x80000007 0x00fd72 2
192.168.0.129   192.168.0.129   262         0x80000007 0x00018e 3

                Net Link States (Area 0)
Link ID         ADV Router      Age         Seq#       Checksum
192.168.0.129   192.168.0.129   262         0x80000003 0x007aac
192.168.0.6     192.168.0.129   262         0x80000004 0x009abe
Router>
```

（R3(R5)的 router id）

```
Router>show ip ospf database
            OSPF Router with ID (192.168.0.5) (Process ID 34)

                Router Link States (Area 0)

Link ID         ADV Router      Age         Seq#       Checksum Link count
192.168.0.5     192.168.0.5     1043        0x80000007 0x00fd72 2
192.168.0.9     192.168.0.9     1043        0x80000006 0x00f818 2
192.168.0.129   192.168.0.129   209         0x80000007 0x00018e 3

                Net Link States (Area 0)
Link ID         ADV Router      Age         Seq#       Checksum
192.168.0.129   192.168.0.129   209         0x80000003 0x007aac
192.168.0.6     192.168.0.129   209         0x80000004 0x009abe
Router>
```

（R1(R3)的 router id）

这和我们之前实验中的 router id 一致，说明在本实验的此场景下，router id 并没有发生变化，因为两者的 router id 一个是自己的接口 id，一个是自己配置的环回 id。

- 打开 debug（命令：debug ip ospf events），记录部分 ospf 事件，然后关闭 debug

在三个路由器上打开 debug 模式：

```
Router>en
Router#debug ip ospf events
OSPF events debugging is on
Router#
```

在打开 debug 模式较短时间后，IOS 命令行上随即出现较多 ospf 事件，并处于不断更新状态，截取其中一部分如下：

```
00:53:21: OSPF: End of hello processing

00:53:31: OSPF: Rcv hello from 192.168.0.129 area 0 from Ethernet7/0 192.168.0.6

00:53:31: OSPF: End of hello processing

00:53:41: OSPF: Rcv hello from 192.168.0.129 area 0 from Ethernet7/0 192.168.0.6

00:53:41: OSPF: End of hello processing

00:53:51: OSPF: Rcv hello from 192.168.0.129 area 0 from Ethernet7/0 192.168.0.6

00:53:51: OSPF: End of hello processing

00:54:01: OSPF: Rcv hello from 192.168.0.129 area 0 from Ethernet7/0 192.168.0.6

00:54:01: OSPF: End of hello processing

00:54:11: OSPF: Rcv hello from 192.168.0.129 area 0 from Ethernet7/0 192.168.0.6

00:54:11: OSPF: End of hello processing

00:54:21: OSPF: Rcv hello from 192.168.0.129 area 0 from Ethernet7/0 192.168.0.6

00:54:21: OSPF: End of hello processing
```

（R1（本题中 R3）的 ospf 信息）

```
00:54:41: OSPF: End of hello processing

00:54:41: OSPF: Rcv hello from 192.168.0.9 area 0 from FastEthernet1/0 192.168.0
.130

00:54:41: OSPF: End of hello processing

00:54:51: OSPF: Rcv hello from 192.168.0.9 area 0 from FastEthernet1/0 192.168.0
.130

00:54:51: OSPF: End of hello processing

00:54:51: OSPF: Rcv hello from 192.168.0.5 area 0 from Ethernet6/0 192.168.0.5

00:54:51: OSPF: End of hello processing

00:55:01: OSPF: Rcv hello from 192.168.0.9 area 0 from FastEthernet1/0 192.168.0
.130

00:55:01: OSPF: End of hello processing

00:55:01: OSPF: Rcv hello from 192.168.0.5 area 0 from Ethernet6/0 192.168.0.5

00:55:01: OSPF: End of hello processing
```

（R2（本题中 R4）的 ospf 信息）

```
00:55:01: OSPF: Rcv hello from 192.168.0.129 area 0 from FastEthernet1/0 192.168
.0.129

00:55:01: OSPF: End of hello processing

00:55:11: OSPF: Rcv hello from 192.168.0.129 area 0 from FastEthernet1/0 192.168
.0.129

00:55:11: OSPF: End of hello processing

00:55:21: OSPF: Rcv hello from 192.168.0.129 area 0 from FastEthernet1/0 192.168
.0.129

00:55:21: OSPF: End of hello processing

00:55:31: OSPF: Rcv hello from 192.168.0.129 area 0 from FastEthernet1/0 192.168
.0.129

00:55:31: OSPF: End of hello processing

00:55:41: OSPF: Rcv hello from 192.168.0.129 area 0 from FastEthernet1/0 192.168
.0.129

00:55:41: OSPF: End of hello processing
```

（R3（本题中 R6）的 ospf 信息）

最后，在三台路由器上运行以下命令（no debug ip ospf events）在三个服务器上关闭 debug 模式(图中命令被打印的 ospf 信息截断了)：

```
Router#no deb
00:59:41: OSPF: Rcv hello from 192.168.0.129 area 0 from FastEthernet1/0 192.168
.0.129

00:59:41: OSPF: End of hello processing
ug ip ospf events
OSPF events debugging is off
Router#
```

- 记录各路由器的路由表内容（命令：show ip route）

R1:

```
Router#show ip route
Codes: C - connected, S - static, I - IGRP, 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, E - EGP
       i - IS-IS, 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

     10.0.0.0/16 is subnetted, 2 subnets
C       10.0.0.0 is directly connected, FastEthernet1/0
O       10.1.0.0 [110/11] via 192.168.0.6, 00:45:43, Ethernet7/0
     192.168.0.0/24 is variably subnetted, 3 subnets, 2 masks
C       192.168.0.4/30 is directly connected, Ethernet7/0
O       192.168.0.9/32 [110/12] via 192.168.0.6, 00:45:43, Ethernet7/0
O       192.168.0.128/30 [110/11] via 192.168.0.6, 00:45:43, Ethernet7/0
```

R2:

```
Codes: C - connected, S - static, I - IGRP, 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, E - EGP
       i - IS-IS, 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

     10.0.0.0/16 is subnetted, 2 subnets
O       10.0.0.0 [110/11] via 192.168.0.5, 00:46:12, Ethernet6/0
C       10.1.0.0 is directly connected, FastEthernet0/0
     192.168.0.0/24 is variably subnetted, 3 subnets, 2 masks
C       192.168.0.4/30 is directly connected, Ethernet6/0
O       192.168.0.9/32 [110/2] via 192.168.0.130, 01:02:16, FastEthernet1/0
C       192.168.0.128/30 is directly connected, FastEthernet1/0
```

R3:

```
Router#show ip route
Codes: C - connected, S - static, I - IGRP, 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, E - EGP
       i - IS-IS, 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

     10.0.0.0/16 is subnetted, 2 subnets
O       10.0.0.0 [110/12] via 192.168.0.129, 00:46:35, FastEthernet1/0
O       10.1.0.0 [110/2] via 192.168.0.129, 01:02:40, FastEthernet1/0
     192.168.0.0/24 is variably subnetted, 3 subnets, 2 masks
O       192.168.0.4/30 [110/11] via 192.168.0.129, 00:46:35, FastEthernet1/0
C       192.168.0.9/32 is directly connected, Loopback0
C       192.168.0.128/30 is directly connected, FastEthernet1/0
```

- 记录各路由器上的运行配置（命令:show running-config），截取本节相关的内容

  此处只截图与本节相关的部分内容，完整的运行配置请保存在单独的文本文件中，一个设备一个文件，如 R1.txt（路由器 1），随报告一起打包上交（看完请删除本句）

R1：

```
interface FastEthernet0/0
 ip address 192.168.0.1 255.255.255.252
 duplex auto
 speed auto
!
interface FastEthernet1/0
 ip address 10.0.0.1 255.255.0.0
 duplex auto
 speed auto
!
interface Serial2/0
 no ip address
 shutdown
!
interface Serial3/0
 no ip address
 shutdown
!
interface FastEthernet4/0
 no ip address
 shutdown
!
interface FastEthernet5/0
 no ip address
 shutdown
!
interface GigabitEthernet6/0
 no ip address
 shutdown
!
interface Ethernet7/0
 ip address 192.168.0.5 255.255.255.252
 duplex auto
 speed auto
!
router ospf 34
 log-adjacency-changes
 network 192.168.0.0 0.0.0.255 area 0
 network 10.0.0.0 0.0.0.255 area 0
!
```

R2:

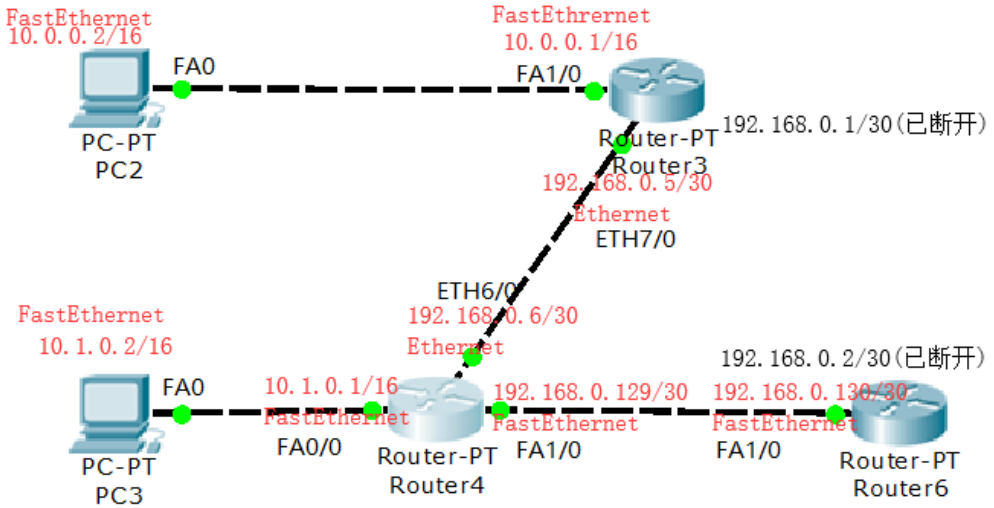
```
.
interface FastEthernet0/0
 ip address 10.1.0.1 255.255.0.0
 duplex auto
 speed auto
!
interface FastEthernet1/0
 ip address 192.168.0.129 255.255.255.252
 duplex auto
 speed auto
!
interface Serial2/0
 no ip address
 shutdown
!
interface Serial3/0
 no ip address
 shutdown
!
interface FastEthernet4/0
 no ip address
!
interface FastEthernet5/0
 no ip address
!
interface Ethernet6/0
 ip address 192.168.0.6 255.255.255.252
 duplex auto
 speed auto
!
interface FastEthernet7/0
 no ip address
!
router ospf 34
 log-adjacency-changes
 network 192.168.0.0 0.0.0.255 area 0
 network 10.1.0.0 0.0.0.255 area 0
!
```

R3:

```
interface Loopback0
 ip address 192.168.0.9 255.255.255.255
!
interface FastEthernet0/0
 ip address 192.168.0.2 255.255.255.252
 duplex auto
 speed auto
!
interface FastEthernet1/0
 ip address 192.168.0.130 255.255.255.252
 duplex auto
 speed auto
!
interface Serial2/0
 no ip address
 shutdown
!
interface Serial3/0
 no ip address
 shutdown
!
interface FastEthernet4/0
 no ip address
!
interface FastEthernet5/0
 no ip address
!
router ospf 34
 log-adjacency-changes
 network 192.168.0.0 0.0.0.255 area 0
!
```

详细请见 txt 文本中的内容。

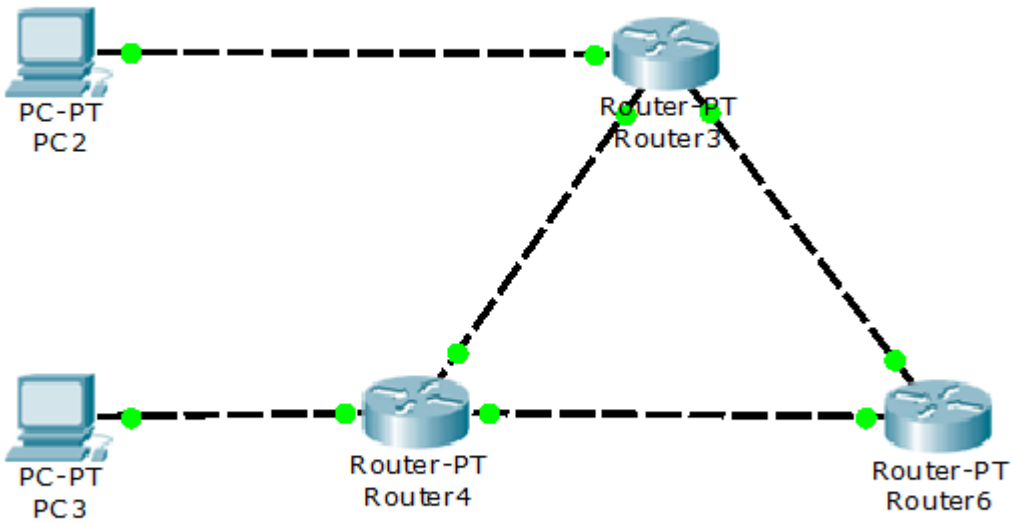
- 记录本部分的最后完整实验拓扑图（标记路由器型号、连接端口、PC 的 IP 地址、路由器各端口的 IP 地址）



----Part 2. 多域 OSPF 路由协议配置-----

- 重新连接 R1 和 R3 的接口，给路由器 R1 的回环接口配置 IP 地址，并在 OSPF 中宣告回环口的 IP 网络属于 Area 0，保存配置后重启路由器（命令：write, reload），再次查看 R1 的 Router ID（命令：show ip ospf）是否已经变成了回环口的 IP 地址

首先，重新连接 R1 和 R3 的接口：



然后给 R1 回环接口配置 IP 地址，假设我们将该回环地址配置为 192.168.0.10：

```
Router#conf
Configuring from terminal, memory, or network [terminal]?
Enter configuration commands, one per line.  End with CNTL/Z.
Router(config)#interface loopback 0

Router(config-if)#
%LINK-5-CHANGED: Interface Loopback0, changed state to up

%LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback0, changed state to up

Router(config-if)#ip address 192.168.0.10 255.255.255.255
Router(config-if)#end
Router#
%SYS-5-CONFIG_I: Configured from console by console

Router#write
Building configuration...
[OK]
Router#
```

查看配置文件，可以看到环路地址配置是成功的：

```
!
interface Loopback0
 ip address 192.168.0.10 255.255.255.255
```

然后我们查看 R1 的 router ID：

```
Router#
Router#show ip ospf
 Routing Process "ospf 34" with ID 192.168.0.5
 Supports only single TOS(TOS0) routes
 Supports opaque LSA
 SPF schedule delay 5 secs, Hold time between two SPFs 10 secs
 Minimum LSA interval 5 secs. Minimum LSA arrival 1 secs
 Number of external LSA 0. Checksum Sum 0x000000
 Number of opaque AS LSA 0. Checksum Sum 0x000000
 Number of DCbitless external and opaque AS LSA 0
```

却发现还是原来的 ID，并没有变。此时我意识到需要 write 后重启路由器：

```
Building configuration...
[OK]
Router#reload
Proceed with reload? [confirm]c
Router#onfirm
Translating "onfirm"...domain server (255.255.255.255) % Name lookup aborted
Router#
Router#reload
Proceed with reload? [confirm]
System Bootstrap, Version 12.1(3r)T2, RELEASE SOFTWARE (fc1)
Copyright (c) 2000 by cisco Systems, Inc.
PT 1001 (PTSC2005) processor (revision 0x200) with 60416K/5120K bytes of memory

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```

然后再查看 router ID：

```
Router>show ip ospf
 Routing Process "ospf 34" with ID 192.168.0.10
 Supports only single TOS(TOS0) routes
 Supports opaque LSA
```

发现这个时候的 router ID 已经修改成功了。

- 分别在 R1、R2、R3 上重新宣告 R1-R3、R2-R3 之间的子网属于 Area 1，同样保存配置后重启路由器

R1:

```
Router#en
Router#conf
Configuring from terminal, memory, or network [terminal]?
Enter configuration commands, one per line.  End with CNTL/Z.
Router(config)#router ospf 34
Router(config-router)#network 192.168.0.0 0.0.255.255 area 1
```

R2:

```
Router#conf
Configuring from terminal, memory, or network [terminal]?
Enter configuration commands, one per line.  End with CNTL/Z.
Router(config)#router ospf 34
Router(config-router)#network 192.168.0.128 0.0.255.255 area 1
Router(config-router)#end
04:03:14: %OSPF-5-ADJCHG: Process 34, Nbr 192.168.0.9 on FastEthernet1/0 from LO
ADING to FULL, Loading Done

04:03:18: %OSPF-5-ADJCHG: Process 34, Nbr 192.168.0.10 on Ethernet6/0 from LOADI
NG to FULL, Loading Done

Router#
%SYS-5-CONFIG_I: Configured from console by console

04:03:19: %OSPF-5-ADJCHG: Process 34, Nbr 192.168.0.9 on FastEthernet1/0 from LO
ADING to FULL, Loading Done
write
Building configuration...
[OK]
Router#reload
Proceed with reload? [confirm]
```

R3:

```
Router>en
Router#conf
Configuring from terminal, memory, or network [terminal]?
Enter configuration commands, one per line.  End with CNTL/Z.
Router(config)#router ospf 34
Router(config-router)#network 192.168.0.0 0.0
04:01:58: %OSPF-5-ADJCHG: Process 34, Nbr 192.168.0.10 on FastEthernet0/0 from E
XSTART to DOWN, Neighbor Down: Dead timer expired

04:01:58: %OSPF-5-ADJCHG: Process 34, Nbr 192.168.0.10 on FastEthernet0/0 from E
XSTART to DOWN, Neighbor Down: Interface down or detached
255.255 area 1
Router(config-router)#end
```

（没配置完的时候因为 area 错配弹出很多报错，影响了视觉和输入体验，不过重新加载后都没有报错了）

（之前提到了 0.0.255.255 输错的问题，我这里进行了重新配置。因此本部分命令截图中出现的均为正确的 0.0.255.255）

- 查看 R3 上的路由表，标出区域间路由（IA）

```
Router#show ip route
Codes: C - connected, S - static, I - IGRP, 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, E - EGP
       i - IS-IS, 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

     10.0.0.0/16 is subnetted, 1 subnets
O IA    10.1.0.0 [110/2] via 192.168.0.129, 00:37:08, FastEthernet1/0
     192.168.0.0/24 is variably subnetted, 5 subnets, 2 masks
C       192.168.0.0/30 is directly connected, FastEthernet0/0
O       192.168.0.4/30 [110/11] via 192.168.0.129, 00:37:08, FastEthernet1/0
C       192.168.0.9/32 is directly connected, Loopback0
O       192.168.0.10/32 [110/12] via 192.168.0.129, 00:37:08, FastEthernet1/0
C       192.168.0.128/30 is directly connected, FastEthernet1/0
```

- 分别在 R1、R2、R3 上查看区域边界路由器（ABR）信息（命令：show ip ospf border-routers）

R1:

```
Router>show ip ospf border-routers
OSPF Process 34 internal Routing Table

Codes: i - Intra-area route, I - Inter-area route

i 192.168.0.129 [10] via 192.168.0.6, Ethernet6/0, ABR, Area 1, SPF 10
i 192.168.0.9 [11] via 192.168.0.6, Ethernet6/0, ABR, Area 1, SPF 11
```

R2:

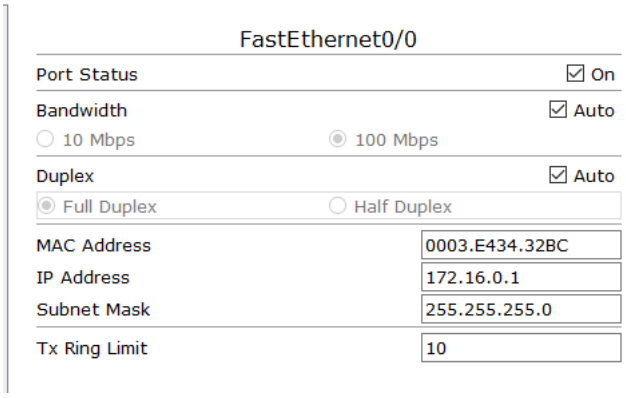
```
Router>show ip ospf border-routers
OSPF Process 34 internal Routing Table

Codes: i - Intra-area route, I - Inter-area route

i 192.168.0.9 [1] via 192.168.0.130, FastEthernet1/0, ABR, Area 1, SPF 1
```

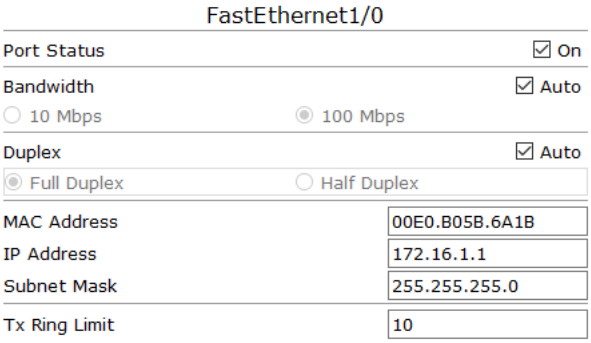
R3:

```
Router#show ip ospf border-routers
OSPF Process 34 internal Routing Table

Codes: i - Intra-area route, I - Inter-area route

i 192.168.0.129 [1] via 192.168.0.129, FastEthernet1/0, ABR, Area 1, SPF 1
```

- 激活路由器 R4 各接口，并配置 IP 地址。同时也给路由器 R4 回环接口配置 IP 地址（命令：interface loopback 0, ip address x.x.x.x 255.255.255.0）

R4 接口 IP 地址配置如下：





R4 环回地址配置如下：

```
                    ^
% Invalid input detected at '^' marker.

Router(config-if)#exit
Router(config)#interface loopback 0
Router(config-if)#ip address 172.16.3.1
% Incomplete command.
Router(config-if)#ip address 172.16.3.1 255.255.255.0
Router(config-if)#end
Router#
%SYS-5-CONFIG_I: Configured from console by console
write
Building configuration...
[OK]
Router#reload
Proceed with reload? [confirm]
System Bootstrap, Version 12.1(3r)T2, RELEASE SOFTWARE (fc1)
Copyright (c) 2000 by cisco Systems, Inc.
PT 1001 (PTSC2005) processor (revision 0x200) with 60416K/5120K bytes of memory

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```
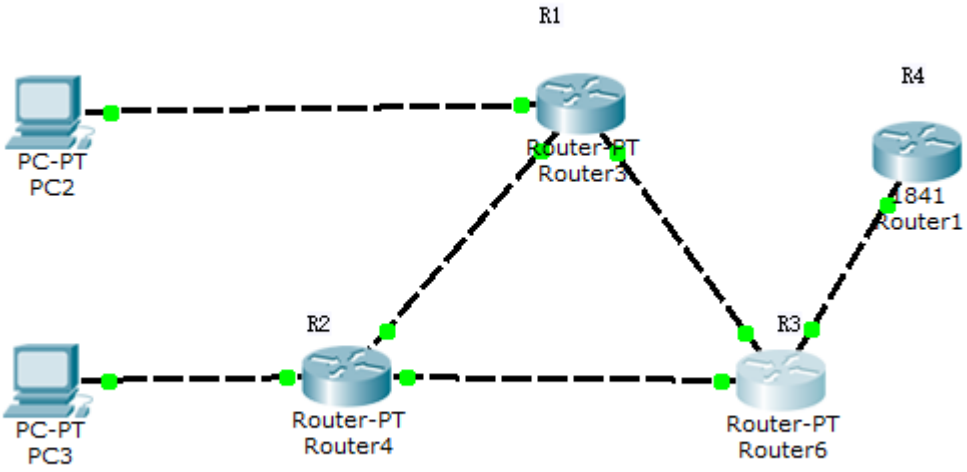

- 激活路由器 R4 的 OSPF 动态路由协议（命令：router ospf 进程 ID），其中进程 ID 请设置为学号的后 2 位。并宣告各子网地址（包括回环接口地址）所属区域为 Area 2（命令：network A.B.C.D x.x.x.x area 2）。

  使用如下命令激活 R4 的 OSPF 动态路由协议，并宣告三个子网地址所属区域为 area 2：

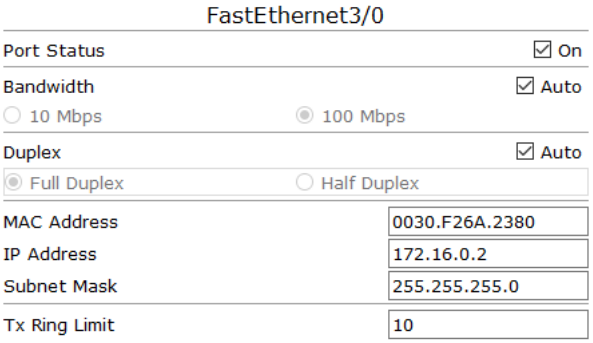
```
Router(config-if)#exit
Router(config)#router ospf 34
Router(config-router)#network 172.16.0.0 0.0.0.255 area 2
Router(config-router)#network 172.16.1.0 0.0.0.255 area 2
Router(config-router)#end
Router#
%SYS-5-CONFIG_I: Configured from console by console

Router#write
Building configuration...
[OK]
Router#
```

- 在 R3 上宣告 R3-4 之间的子网属于 Area 2。

  首先将 R3 同 R4 连接：



配置 R3 的 IP 地址使其落在一个子网下：



最后进行宣告：

```
Router>en
Router#con
% Ambiguous command: "con"
Router# conf
Configuring from terminal, memory, or network [terminal]?
Enter configuration commands, one per line.  End with
CNTL/Z.
Router(config)#router ospf 34
Router(config-router)#network 172.16.0.0 0.0.0.255 area 2
Router(config-router)#end
Router#
%SYS-5-CONFIG_I: Configured from console by console
wrtie
Translating "wrtie"...domain server (255.255.255.255) %
Name lookup aborted
Router#write
Building configuration...
[OK]
```

- 在 R4 上显示 OSPF 邻居信息，R3 的 Router ID 是否已在其中

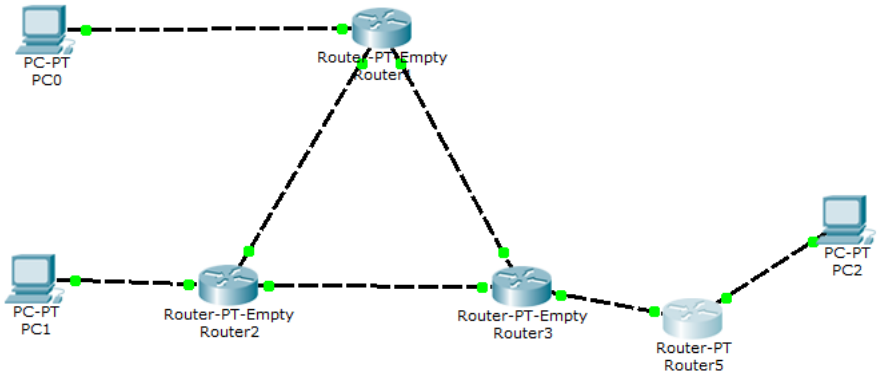
```
Neighbor ID     Pri   State           Dead Time   Address
Interface
4.4.4.4           1   FULL/BDR        00:00:33
```

【注：由于之前配置环回地址之后出现误操作导致系统错误，我将拓扑进行了重构，重新配置了 R3 的环回地址，因此其 router ID 和之前有出入】

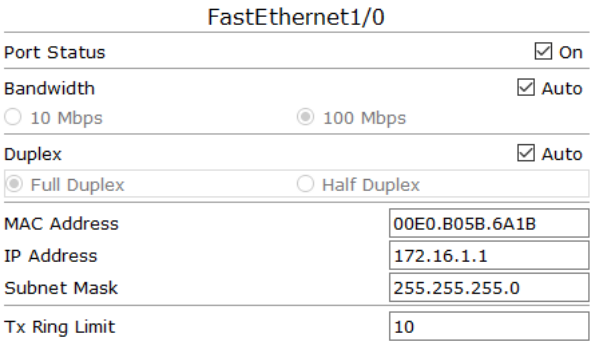
可以看到 R3 的 router ID 已经在 R4 的邻居中了。

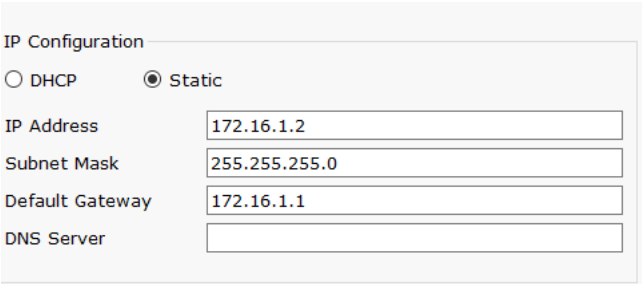
- 配置 PC3 的 IP 地址和默认网关，然后使用 Ping 测试 PC3 与其他 PC 的结果

首先将 PC3 与 R4 连接：

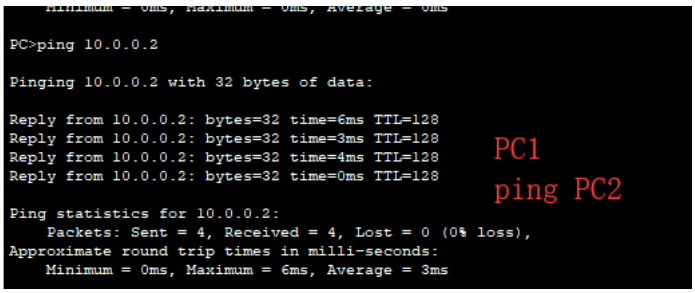


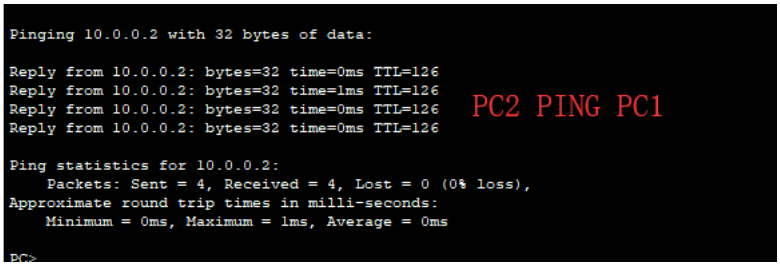
然后配置 R4 和 PC3 的 IP 地址，并把 R4 配置为 PC3 的默认网关：

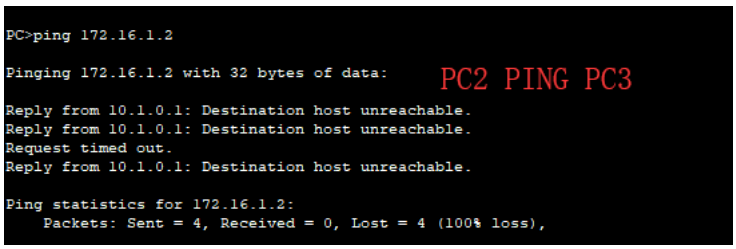


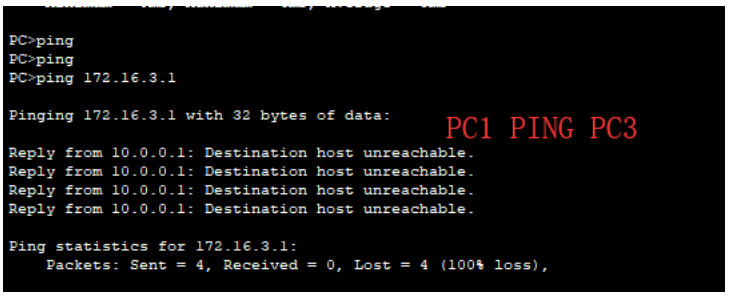


各 PC 互 ping 测试：









可以看出 PC1 和 PC2 是可以互相 ping 通的，而 PC3 和 PC12 中任意一个都无法互相 ping 通。这是因为我们还没有建立虚链路。

- 显示此时 R3、R4 的路由表，是否存在 PC1，PC2 所在的子网

R3:

Routing Table for Router3

Type	Network	Port	Next Hop IP	Metric
C	172.16.0.0/24	FastEthernet3/0	---	0/0
C	192.168.0.0/30	FastEthernet2/0	---	0/0
C	192.168.0.128/30	FastEthernet1/0	---	0/0
C	192.168.0.8/30	Loopback0	---	0/0
O	10.0.0.0/16	FastEthernet2/0	192.168.0.1	110/2
O	10.1.0.0/16	FastEthernet1/0	192.168.0.129	110/2
O	192.168.0.13/32	FastEthernet2/0	192.168.0.1	110/2
O	192.168.0.4/30	FastEthernet1/0	192.168.0.129	110/11
O	192.168.0.4/30	FastEthernet2/0	192.168.0.1	110/11

此时 R3 上已经有 R3、R4 的路由表项了

R4:

Routing Table for Router5

Type	Network	Port	Next Hop IP	Metric
C	172.16.0.0/24	FastEthernet0/0	---	0/0
C	172.16.1.0/24	FastEthernet1/0	---	0/0

而 R4 此时还没有，这便是没有建立虚链路的缘故。

- 在 R1 上创建虚链路（命令：area 1 virtual-link RID），RID 写 R3 的 Router ID

  如图，在 R1 上输入以下命令创建虚链路：

```
Router#conf
Configuring from terminal, memory, or network [terminal]?
Enter configuration commands, one per line.  End with CNTL/Z.
Router(config)#router ospf 34
Router(config-router)#area 1 virtual link 192.168.0.9
                                          ^
% Invalid input detected at '^' marker.

Router(config-router)#area 1 virtual-link 192.168.0.9
Router(config-router)#end
Router#
%SYS-5-CONFIG_I: Configured from console by console
write
Building configuration...
[OK]
Router#
```

- 在 R3 上创建虚链路（命令：area 1 virtual-link RID），RID 写 R1 的 Router ID。打开 debug，观察 R3 上的 OSPF 事件，是否出现 virtual link 建立事件，是否收到关于 Area 0 的信息。观察完毕关闭 debug。查看虚链路建立情况（命令：show ip ospf virtual-links）。

  如图，在 R3 上建立虚链路：

```
Router>en
Router#conf
Configuring from terminal, memory, or network [terminal]?
Enter configuration commands, one per line.  End with CNTL/Z.
Router(config)#router ospf
01:28:43: %OSPF-4-ERRRCV: Received invalid packet: mismatch area ID, from backbo
ne area must be virtual-link but not found from 192.168.0.2, FastEthernet2/0
 34
Router(config-router)#area 1 virtual-lin
01:28:53: %OSPF-4-ERRRCV: Received invalid packet: mismatch area ID, from backbo
ne area must be virtual-link but not found from 192.168.0.2, FastEthernet2/0
k
01:29:03: %OSPF-4-ERRRCV: Received invalid packet: mismatch area ID, from backbo
ne area must be virtual-link but not found from 192.168.0.2, FastEthernet2/0

01:29:13: %OSPF-4-ERRRCV: Received invalid packet: mismatch area ID, from backbo
ne area must be virtual-link but not found from 192.168.0.2, FastEthernet2/0
192.168.0.13
01:29:23: %OSPF-4-ERRRCV: Received invalid packet: mismatch area ID, from backbo
ne area must be virtual-link but not found from 192.168.0.2, FastEthernet2/0

Router(config-router)#end
Router#
%SYS-5-CONFIG_I: Configured from console by console
write
Building configuration...
[OK]
```

观察 OSPF 事件：

```
01:31:51: OSPF: End of hello processing

01:31:51: OSPF: Rcv hello from 192.168.0.13 area 1 from FastEthernet2/0 192.168.
0.1

01:31:51: OSPF: End of hello processing

01:31:53: OSPF: Rcv hello from 192.168.0.13 area 0 from FastEthernet2/0 192.168.
0.1

01:31:53: OSPF: Cannot see ourself in hello from 192.168.0.1 on OSPF_VL0, state
INIT

01:31:53: OSPF: Send immediate hello to nbr 192.168.0.1, src address 192.168.0.1
 on OSPF_VL0

01:31:53: OSPF: End of hello processing

01:32:01: OSPF: Rcv hello from 192.168.0.129 area 1 from FastEthernet1/0 192.168
.0.129

01:32:01: OSPF: End of hello processing

01:32:01: OSPF: Rcv hello from 192.168.0.13 area 1 from FastEthernet2/0 192.168.
0.1

01:32:01: OSPF: End of hello processing

01:32:03: OSPF: Rcv hello from 192.168.0.13 area 0 from FastEthernet2/0 192.168.
0.1

01:32:03: OSPF: Cannot see ourself in hello from 192.168.0.1 on OSPF_VL0, state
INIT

01:32:03: OSPF: Send immediate hello to nbr 192.168.0.1, src address 192.168.0.1
 on OSPF_VL0

01:32:03: OSPF: End of hello processing
```

可以看到，出现 virtual-link 建立事件和来自 area 0 的消息。

检查虚链路的建立情况：

```
Router#show ip ospf virtual-links
Virtual Link OSPF_VL0 to router 192.168.0.13 is up
  Run as demand circuit
  Transit area 1, via interface FastEthernet2/0, Cost of using 1
  Transmit Delay is 1 sec, State POINT_TO_POINT,
  Timer intervals configured, Hello 10, Dead 40, Wait 40, Retransmit 5
    Hello due in 00:00:05
    Adjacency State INIT
    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
```

- 在 R3 上查看邻居的详细信息（命令：show ip ospf neighbor detail），标出 R3-R1 建立邻居关系的 Interface、Area。

  输入以下命令查看邻居的详细信息：

```
Router>show ip ospf neighbor detail
 Neighbor 192.168.0.129, interface address 192.168.0.129
    In the area 1 via interface FastEthernet1/0
    Neighbor priority is 1, State is FULL, 6 state changes
    DR is 192.168.0.129 BDR is 192.168.0.130
    Options is 0x00
    Dead timer due in 00:00:38
    Neighbor is up for 02:18:43
    Index 1/1, retransmission queue length 0, number of retransmission 0
    First 0x0(0)/0x0(0) Next 0x0(0)/0x0(0)
    Last retransmission scan length is 0, maximum is 2
    Last retransmission scan time is 0 msec, maximum is 0 msec
 Neighbor 192.168.0.13, interface address 192.168.0.1
    In the area 1 via interface FastEthernet2/0
    Neighbor priority is 1, State is FULL, 6 state changes
    DR is 192.168.0.1 BDR is 192.168.0.2
    Options is 0x00
    Dead timer due in 00:00:38
    Neighbor is up for 02:18:43
    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 192.168.0.13, interface address 192.168.0.1
    In the area 0 via interface OSPF_VL0
    Neighbor priority is 0, State is INIT, 2 state changes
    DR is 0.0.0.0 BDR is 0.0.0.0
    Options is 0x00
    Dead timer due in 00:00:31
    Neighbor is up for 00:49:00
    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 R3 上显示区域边界路由器（ABR）信息，标出新增加的部分。

```
Router#show ip ospf border-routers
OSPF Process 34 internal Routing Table

Codes: i - Intra-area route, I - Inter-area route

i 1.1.1.1 [1] via 192.168.0.1, FastEthernet0/0, ABR, Area 1, SPF 1
i 192.168.0.129 [1] via 192.168.0.129, FastEthernet1/0, ABR, Area 1, SPF 1
i 1.1.1.1 [2] via 192.168.0.1, FastEthernet0/0, ABR, Area 0, SPF 2
i 192.168.0.129 [11] via 192.168.0.1, FastEthernet0/0, ABR, Area 0, SPF 11
OSPF Process 3 internal Routing Table

Codes: i - Intra-area route, I - Inter-area route
```

- 再次显示此时 R3、R4 的路由表，是否存在 PC1、PC2 所在的子网（有则标出）

  R3:

  Routing Table for Router0

Type	Network	Port	Next Hop IP	Metric
C	172.16.0.0/24	FastEthernet6/0	---	0/0
C	192.168.0.0/30	FastEthernet0/0	---	0/0
C	192.168.0.128/30	FastEthernet1/0	---	0/0
C	4.4.4.4/32	Loopback0	---	0/0
O	10.0.0.0/16	FastEthernet0/0	192.168.0.1	110/2
O	10.1.0.0/16	FastEthernet1/0	192.168.0.129	110/12
O	172.16.1.0/24	FastEthernet6/0	172.16.0.1	110/2
O	192.168.0.4/30	FastEthernet0/0	192.168.0.1	110/11
O	192.168.0.4/30	FastEthernet1/0	192.168.0.129	110/11

  可以看出 R3 是有的。

  R4:

  Routing Table for Router3

Type	Network	Port	Next Hop IP	Metric
C	172.16.0.0/24	FastEthernet0/0	---	0/0
C	172.16.1.0/24	FastEthernet1/0	---	0/0
O	10.0.0.0/16	FastEthernet0/0	172.16.0.2	110/3
O	10.1.0.0/16	FastEthernet0/0	172.16.0.2	110/13
O	192.168.0.4/30	FastEthernet0/0	172.16.0.2	110/12

  R4 也是有的。说明我们搭建虚拟链路成功了。

- 在 R3 上手工合并 Area 0 上的子网路由（命令：area 0 range <ip_net> <mask>，例如假设 10.x.x.x 的网络都在 area 0 上，那么把所有 10.x.x.x 的网络合并成 1 条的命令就是：area 0 range 10.0.0.0 255.0.0.0），然后显示 R3 和 R4 的路由表，看看所指定的子网是否合并了路由

  【注：之前我的实验是用 6.0 版本的 PT 完成的，但做到这里时发现 6.0 不支持这个命令，因此之后实验的部分内容我是使用最新版的 7.2 完成的】

  我们之前看到的路由表中，路由是没有合并的，这里我们在 R3 上进行路由合并

```
Router(config)#router ospf 34
Router(config-router)#area 0 range 10.0.0.0 255.0.0.0
Router(config-router)#end
Router#
%SYS-5-CONFIG_I: Configured from console by console
write
Building configuration...
[OK]
```

重启 R3 并等待一段时间　后，结果如下（7.2 版本的路由表截图）：

R3:

C	4.4.4.4/32	Loopback0	---	0/0
O	10.0.0.0/16	FastEthernet0/0	192.168.0.1	110/2
O	10.0.0.0/16	FastEthernet1/0	192.168.0.129	110/2
O	10.1.0.0/16	FastEthernet1/0	192.168.0.129	110/12
C	172.16.0.0/24	FastEthernet6/0	---	0/0
O	172.16.1.0/24	FastEthernet6/0	172.16.0.1	110/2
C	192.168.0.0/30	FastEthernet0/0	---	0/0
O	192.168.0.4/30	FastEthernet1/0	192.168.0.129	110/11
O	192.168.0.4/30	FastEthernet0/0	192.168.0.1	110/11
C	192.168.0.128/30	FastEthernet1/0	---	0/0

发现 R3 多了一个合并后的表项，但是原来的表项没有删除。

R4:

O	10.0.0.0/16	FastEthernet0/0	172.16.0.2	110/3
C	172.16.0.0/24	FastEthernet0/0	---	0/0
C	172.16.1.0/24	FastEthernet1/0	---	0/0
O	192.168.0.0/30	FastEthernet0/0	172.16.0.2	110/2
O	192.168.0.4/30	FastEthernet0/0	172.16.0.2	110/12
O	192.168.0.128/30	FastEthernet0/0	172.16.0.2	110/2

发现 R4 先前的两个表项被完全合并。

- 记录 4 台路由器的 OSPF 数据库内容（命令：show ip ospf database）

R1:

```
Router>show ip ospf database
            OSPF Router with ID (1.1.1.1) (Process ID 34)

                Router Link States (Area 0)

Link ID         ADV Router      Age         Seq#       Checksum Link count
1.1.1.1         1.1.1.1         558         0x80000005 0x003c7d 3
4.4.4.4         4.4.4.4         497         0x80000002 0x004879 1
192.168.0.129   192.168.0.129   210         0x80000006 0x00abc9 2

                Net Link States (Area 0)
Link ID         ADV Router      Age         Seq#       Checksum
192.168.0.6     192.168.0.129   210         0x80000003 0x0069d2

                Summary Net Link States (Area 0)
Link ID         ADV Router      Age         Seq#       Checksum
192.168.0.0     1.1.1.1         1059        0x80000007 0x00a548
192.168.0.128   1.1.1.1         1054        0x80000008 0x00a8c2
192.168.0.128   192.168.0.129   1064        0x80000007 0x00a9dc
192.168.0.0     192.168.0.129   1064        0x80000008 0x00b64e
192.168.0.0     4.4.4.4         497         0x80000005 0x004f94
192.168.0.128   4.4.4.4         497         0x80000006 0x00481a
172.16.0.0      4.4.4.4         497         0x80000007 0x008902
172.16.1.0      4.4.4.4         497         0x80000008 0x008602

                Router Link States (Area 1)

Link ID         ADV Router      Age         Seq#       Checksum Link count
1.1.1.1         1.1.1.1         559         0x8000000c 0x006902 1
192.168.0.129   192.168.0.129   1069        0x80000009 0x00e7b8 1
4.4.4.4         4.4.4.4         497         0x80000007 0x000e62 2

                Net Link States (Area 1)
Link ID         ADV Router      Age         Seq#       Checksum
192.168.0.129   192.168.0.129   1069        0x80000004 0x00b260
192.168.0.2     4.4.4.4         1065        0x80000004 0x002503

                Summary Net Link States (Area 1)
Link ID         ADV Router      Age         Seq#       Checksum
192.168.0.4     1.1.1.1         206         0x8000000d 0x00cb0f
10.0.0.0        1.1.1.1         206         0x8000000e 0x00d86a
172.16.0.0      4.4.4.4         497         0x80000015 0x006d10
172.16.1.0      4.4.4.4         497         0x80000016 0x006a10
192.168.0.4     192.168.0.129   199         0x8000001b 0x00b82d
10.1.0.0        192.168.0.129   199         0x8000001c 0x00b993
```

R2:

```
Router>
Router>show ip ospf database
            OSPF Router with ID (192.168.0.129) (Process ID 34)

                Router Link States (Area 0)

Link ID         ADV Router      Age         Seq#       Checksum Link count
192.168.0.129   192.168.0.129   244         0x80000006 0x00abc9 2
1.1.1.1         1.1.1.1         593         0x80000005 0x003c7d 3
4.4.4.4         4.4.4.4         531         0x80000002 0x004879 1

                Net Link States (Area 0)
Link ID         ADV Router      Age         Seq#       Checksum
192.168.0.6     192.168.0.129   244         0x80000003 0x0069d2

                Summary Net Link States (Area 0)
Link ID         ADV Router      Age         Seq#       Checksum
192.168.0.128   192.168.0.129   1098        0x80000007 0x00a9dc
192.168.0.0     192.168.0.129   1098        0x80000008 0x00b64e
192.168.0.0     1.1.1.1         1094        0x80000007 0x00a548
192.168.0.128   1.1.1.1         1089        0x80000008 0x00a8c2
192.168.0.0     4.4.4.4         531         0x80000005 0x004f94
192.168.0.128   4.4.4.4         531         0x80000006 0x00481a
172.16.0.0      4.4.4.4         531         0x80000007 0x008902
172.16.1.0      4.4.4.4         531         0x80000008 0x008602

                Router Link States (Area 1)

Link ID         ADV Router      Age         Seq#       Checksum Link count
192.168.0.129   192.168.0.129   1102        0x80000009 0x00e7b8 1
1.1.1.1         1.1.1.1         593         0x8000000c 0x006902 1
4.4.4.4         4.4.4.4         532         0x80000007 0x000e62 2

                Net Link States (Area 1)
Link ID         ADV Router      Age         Seq#       Checksum
192.168.0.129   192.168.0.129   1102        0x80000004 0x00b260
192.168.0.2     4.4.4.4         1099        0x80000004 0x002503

                Summary Net Link States (Area 1)
Link ID         ADV Router      Age         Seq#       Checksum
192.168.0.4     192.168.0.129   233         0x8000001b 0x00b82d
10.1.0.0        192.168.0.129   233         0x8000001c 0x00b993
172.16.0.0      4.4.4.4         532         0x80000015 0x006d10
172.16.1.0      4.4.4.4         532         0x80000016 0x006a10
192.168.0.4     1.1.1.1         240         0x8000000d 0x00cb0f
10.0.0.0        1.1.1.1         240         0x8000000e 0x00d86a
Router>
```

R3:

```
Router#show ip ospf database
            OSPF Router with ID (4.4.4.4) (Process ID 34)

                Router Link States (Area 0)

Link ID         ADV Router      Age         Seq#       Checksum Link count
4.4.4.4         4.4.4.4         575         0x80000002 0x004879 1
1.1.1.1         1.1.1.1         637         0x80000005 0x003c7d 3
192.168.0.129   192.168.0.129   288         0x80000006 0x00abc9 2

                Net Link States (Area 0)
Link ID         ADV Router      Age         Seq#       Checksum
192.168.0.6     192.168.0.129   288         0x80000003 0x0069d2

                Summary Net Link States (Area 0)
Link ID         ADV Router      Age         Seq#       Checksum
192.168.0.0     4.4.4.4         575         0x80000005 0x004f94
192.168.0.128   4.4.4.4         575         0x80000006 0x00481a
172.16.0.0      4.4.4.4         575         0x80000007 0x008902
172.16.1.0      4.4.4.4         575         0x80000008 0x008602
192.168.0.128   192.168.0.129   1142        0x80000007 0x00a9dc
192.168.0.0     192.168.0.129   1142        0x80000008 0x00b64e
192.168.0.0     1.1.1.1         1138        0x80000007 0x00a548
192.168.0.128   1.1.1.1         1133        0x80000008 0x00a8c2

                Router Link States (Area 1)

Link ID         ADV Router      Age         Seq#       Checksum Link count
4.4.4.4         4.4.4.4         575         0x80000007 0x000e62 2
192.168.0.129   192.168.0.129   1147        0x80000009 0x00e7b8 1
1.1.1.1         1.1.1.1         637         0x8000000c 0x006902 1

                Net Link States (Area 1)
Link ID         ADV Router      Age         Seq#       Checksum
192.168.0.2     4.4.4.4         1143        0x80000004 0x002503
192.168.0.129   192.168.0.129   1147        0x80000004 0x00b260

                Summary Net Link States (Area 1)
Link ID         ADV Router      Age         Seq#       Checksum
172.16.0.0      4.4.4.4         575         0x80000015 0x006d10
172.16.1.0      4.4.4.4         575         0x80000016 0x006a10
192.168.0.4     1.1.1.1         285         0x8000000d 0x00cb0f
10.0.0.0        1.1.1.1         285         0x8000000e 0x00d86a
192.168.0.4     192.168.0.129   277         0x8000001b 0x00b82d
10.1.0.0        192.168.0.129   277         0x8000001c 0x00b993

                Router Link States (Area 2)

Link ID         ADV Router      Age         Seq#       Checksum Link count
4.4.4.4         4.4.4.4         575         0x80000006 0x003f73 1
172.16.1.1      172.16.1.1      892         0x80000004 0x00ddac 2

                Net Link States (Area 2)
Link ID         ADV Router      Age         Seq#       Checksum
172.16.0.1      172.16.1.1      1128        0x80000002 0x008e04

                Summary Net Link States (Area 2)
Link ID         ADV Router      Age         Seq#       Checksum
192.168.0.4     4.4.4.4         555         0x80000004 0x008d49
10.0.0.0        4.4.4.4         555         0x80000005 0x009aa4
10.1.0.0        4.4.4.4         555         0x80000006 0x00f042
```

R4:

```
Router>show ip ospf database
            OSPF Router with ID (172.16.1.1) (Process ID 34)

                Router Link States (Area 2)

Link ID         ADV Router      Age         Seq#       Checksum Link count
172.16.1.1      172.16.1.1      938         0x80000004 0x00ddac 2
4.4.4.4         4.4.4.4         621         0x80000006 0x003f73 1

                Net Link States (Area 2)
Link ID         ADV Router      Age         Seq#       Checksum
172.16.0.1      172.16.1.1      1174        0x80000002 0x008e04

                Summary Net Link States (Area 2)
Link ID         ADV Router      Age         Seq#       Checksum
192.168.0.4     4.4.4.4         602         0x80000004 0x008d49
10.0.0.0        4.4.4.4         602         0x80000005 0x009aa4
10.1.0.0        4.4.4.4         602         0x80000006 0x00f042
```

- 记录 4 台路由器的路由表内容（命令：show ip route）

R1:

```
Router>show ip route
Codes: C - connected, S - static, I - IGRP, 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, E - EGP
       i - IS-IS, 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

     1.0.0.0/32 is subnetted, 1 subnets
C       1.1.1.1 is directly connected, Loopback0
     10.0.0.0/16 is subnetted, 2 subnets
C       10.0.0.0 is directly connected, FastEthernet1/0
O       10.1.0.0 [110/11] via 192.168.0.6, 01:14:25, Ethernet0/0
     172.16.0.0/24 is subnetted, 2 subnets
O IA    172.16.0.0 [110/2] via 192.168.0.2, 00:48:44, FastEthernet2/0
O IA    172.16.1.0 [110/3] via 192.168.0.2, 00:48:44, FastEthernet2/0
     192.168.0.0/30 is subnetted, 3 subnets
C       192.168.0.0 is directly connected, FastEthernet2/0
C       192.168.0.4 is directly connected, Ethernet0/0
O       192.168.0.128 [110/2] via 192.168.0.2, 00:58:30, FastEthernet2/0
```

Routing Table for Router1

Type	Network	Port	Next Hop IP	Metric
C	1.1.1.1/32	Loopback0	---	0/0
C	10.0.0.0/16	FastEthernet1/0	---	0/0
C	192.168.0.0/30	FastEthernet2/0	---	0/0
C	192.168.0.4/30	Ethernet0/0	---	0/0
O	10.1.0.0/16	Ethernet0/0	192.168.0.6	110/11
O	172.16.0.0/24	FastEthernet2/0	192.168.0.2	110/2
O	172.16.1.0/24	FastEthernet2/0	192.168.0.2	110/3
O	192.168.0.128/30	FastEthernet2/0	192.168.0.2	110/2

R2:

```
Router>show ip route
Codes: C - connected, S - static, I - IGRP, 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, E - EGP
       i - IS-IS, 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

     10.0.0.0/16 is subnetted, 2 subnets
O       10.0.0.0 [110/11] via 192.168.0.5, 01:15:34, Ethernet4/0
C       10.1.0.0 is directly connected, FastEthernet0/0
     172.16.0.0/24 is subnetted, 2 subnets
O IA    172.16.0.0 [110/12] via 192.168.0.5, 00:50:02, Ethernet4/0
                   [110/12] via 192.168.0.130, 00:49:57, FastEthernet1/0
O IA    172.16.1.0 [110/13] via 192.168.0.5, 00:50:02, Ethernet4/0
                   [110/13] via 192.168.0.130, 00:49:57, FastEthernet1/0
     192.168.0.0/30 is subnetted, 3 subnets
O       192.168.0.0 [110/2] via 192.168.0.130, 00:59:43, FastEthernet1/0
C       192.168.0.4 is directly connected, Ethernet4/0
C       192.168.0.128 is directly connected, FastEthernet1/0
```

Routing Table for Router2

Type	Network	Port	Next Hop IP	Metric
C	10.1.0.0/16	FastEthernet0/0	---	0/0
C	192.168.0.128/30	FastEthernet1/0	---	0/0
C	192.168.0.4/30	Ethernet4/0	---	0/0
O	10.0.0.0/16	Ethernet4/0	192.168.0.5	110/11
O	172.16.0.0/24	Ethernet4/0	192.168.0.5	110/12
O	172.16.0.0/24	FastEthernet1/0	192.168.0.130	110/12
O	172.16.1.0/24	Ethernet4/0	192.168.0.5	110/13
O	172.16.1.0/24	FastEthernet1/0	192.168.0.130	110/13
O	192.168.0.0/30	FastEthernet1/0	192.168.0.130	110/2

R3:

```
Router>show ip route
Codes: C - connected, S - static, I - IGRP, 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, E - EGP
       i - IS-IS, 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

     4.0.0.0/32 is subnetted, 1 subnets
C       4.4.4.4 is directly connected, Loopback0
     10.0.0.0/16 is subnetted, 2 subnets
O       10.0.0.0 [110/2] via 192.168.0.1, 00:50:32, FastEthernet0/0
O       10.1.0.0 [110/12] via 192.168.0.129, 00:15:38, FastEthernet1/0
     172.16.0.0/24 is subnetted, 2 subnets
C       172.16.0.0 is directly connected, FastEthernet6/0
O       172.16.1.0 [110/2] via 172.16.0.1, 00:56:06, FastEthernet6/0
     192.168.0.0/30 is subnetted, 3 subnets
C       192.168.0.0 is directly connected, FastEthernet0/0
O       192.168.0.4 [110/11] via 192.168.0.1, 00:15:38, FastEthernet0/0
                    [110/11] via 192.168.0.129, 00:15:38, FastEthernet1/0
```

合并前：

Routing Table for Router0

Type	Network	Port	Next Hop IP	Metric
C	172.16.0.0/24	FastEthernet6/0	---	0/0
C	192.168.0.0/30	FastEthernet0/0	---	0/0
C	192.168.0.128/30	FastEthernet1/0	---	0/0
C	4.4.4.4/32	Loopback0	---	0/0
O	10.0.0.0/16	FastEthernet0/0	192.168.0.1	110/2
O	10.1.0.0/16	FastEthernet1/0	192.168.0.129	110/12
O	172.16.1.0/24	FastEthernet6/0	172.16.0.1	110/2
O	192.168.0.4/30	FastEthernet0/0	192.168.0.1	110/11
O	192.168.0.4/30	FastEthernet1/0	192.168.0.129	110/11

合并后：

C	4.4.4.4/32	Loopback0	---	0/0
O	10.0.0.0/16	FastEthernet0/0	192.168.0.1	110/2
O	10.0.0.0/16	FastEthernet1/0	192.168.0.129	110/2
O	10.1.0.0/16	FastEthernet1/0	192.168.0.129	110/12
C	172.16.0.0/24	FastEthernet6/0	---	0/0
O	172.16.1.0/24	FastEthernet6/0	172.16.0.1	110/2
C	192.168.0.0/30	FastEthernet0/0	---	0/0
O	192.168.0.4/30	FastEthernet1/0	192.168.0.129	110/11
O	192.168.0.4/30	FastEthernet0/0	192.168.0.1	110/11
C	192.168.0.128/30	FastEthernet1/0	---	0/0

R4:

```
Router>show ip route
Codes: C - connected, S - static, I - IGRP, 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, E - EGP
       i - IS-IS, L1 - IS-IS level-1, L2 - IS-IS level-2, ia - IS-IS inter a
       * - candidate default, U - per-user static route, o - ODR
       P - periodic downloaded static route

Gateway of last resort is not set

     10.0.0.0/16 is subnetted, 2 subnets
O IA    10.0.0.0 [110/3] via 172.16.0.2, 00:51:23, FastEthernet0/0
O IA    10.1.0.0 [110/13] via 172.16.0.2, 00:51:23, FastEthernet0/0
     172.16.0.0/24 is subnetted, 2 subnets
C       172.16.0.0 is directly connected, FastEthernet0/0
C       172.16.1.0 is directly connected, FastEthernet1/0
     192.168.0.0/30 is subnetted, 1 subnets
O IA    192.168.0.4 [110/12] via 172.16.0.2, 00:51:23, FastEthernet0/0
```

合并前：

Routing Table for Router3

Type	Network	Port	Next Hop IP	Metric
C	172.16.0.0/24	FastEthernet0/0	---	0/0
C	172.16.1.0/24	FastEthernet1/0	---	0/0
O	10.0.0.0/16	FastEthernet0/0	172.16.0.2	110/3
O	10.1.0.0/16	FastEthernet0/0	172.16.0.2	110/13
O	192.168.0.4/30	FastEthernet0/0	172.16.0.2	110/12

合并后：

O	10.0.0.0/16	FastEthernet0/0	172.16.0.2	110/3
C	172.16.0.0/24	FastEthernet0/0	---	0/0
C	172.16.1.0/24	FastEthernet1/0	---	0/0
O	192.168.0.0/30	FastEthernet0/0	172.16.0.2	110/2
O	192.168.0.4/30	FastEthernet0/0	172.16.0.2	110/12
O	192.168.0.128/30	FastEthernet0/0	172.16.0.2	110/2

- 记录 4 台路由器上的运行配置（命令:show running-config），截取本节相关的内容

  此处只截图与本节相关的部分内容，完整的运行配置请保存在单独的文本文件中，一个设备一个文件，如 R1.txt（路由器 1），随报告一起打包上交（看完请删除本句）

  R1:

```
interface Loopback0
 ip address 1.1.1.1 255.255.255.255
!
interface Ethernet0/0
 ip address 192.168.0.5 255.255.255.252
 duplex auto
 speed auto
!
interface FastEthernet1/0
 ip address 10.0.0.1 255.255.0.0
 duplex auto
 speed auto
!
interface FastEthernet2/0
 ip address 192.168.0.1 255.255.255.252
 duplex auto
 speed auto
!
interface FastEthernet3/0
 no ip address
 duplex auto
 speed auto
 shutdown
!
interface FastEthernet4/0
 no ip address
 duplex auto
 speed auto
 shutdown
!
router ospf 34
 router-id 1.1.1.1
 log-adjacency-changes
 area 1 virtual-link 192.168.0.9
 area 1 virtual-link 4.4.4.4
 network 10.0.0.0 0.0.255.255 area 0
 network 192.168.0.4 0.0.0.3 area 0
 network 192.168.0.12 0.0.0.3 area 0
 network 192.168.0.13 0.0.0.0 area 0
 network 192.168.0.0 0.0.0.3 area 1
!
```

R2:

```
!
interface FastEthernet0/0
 ip address 10.1.0.1 255.255.0.0
 duplex auto
 speed auto
!
interface FastEthernet1/0
 ip address 192.168.0.129 255.255.255.252
 duplex auto
 speed auto
!
interface FastEthernet2/0
 no ip address
 duplex auto
 speed auto
!
interface FastEthernet3/0
 no ip address
 duplex auto
 speed auto
!
interface Ethernet4/0
 ip address 192.168.0.6 255.255.255.252
 duplex auto
 speed auto
!
router ospf 34
 log-adjacency-changes
 network 10.1.0.0 0.0.255.255 area 0
 network 192.168.0.4 0.0.0.3 area 0
 network 192.168.0.128 0.0.0.3 area 1
!
ip classless
!
```

R3:

```
!
interface Loopback0
 ip address 4.4.4.4 255.255.255.255
!
interface FastEthernet0/0
 ip address 192.168.0.2 255.255.255.252
 duplex auto
 speed auto
!
interface FastEthernet1/0
 ip address 192.168.0.130 255.255.255.252
 duplex auto
 speed auto
!
interface Serial2/0
 no ip address
 shutdown
!
interface Serial3/0
 no ip address
 shutdown
!
interface FastEthernet4/0
 no ip address
 shutdown
!
interface FastEthernet5/0
 no ip address
 shutdown
!
interface FastEthernet6/0
 ip address 172.16.0.2 255.255.255.0
 duplex auto
 speed auto
!
router ospf 34
 log-adjacency-changes
 area 1 virtual-link 1.1.1.1
 network 192.168.0.0 0.0.0.3 area 1
 network 192.168.0.128 0.0.0.3 area 1
 network 172.16.0.0 0.0.0.255 area 2
!
router ospf 3
 log-adjacency-changes
!
ip classless
!
```

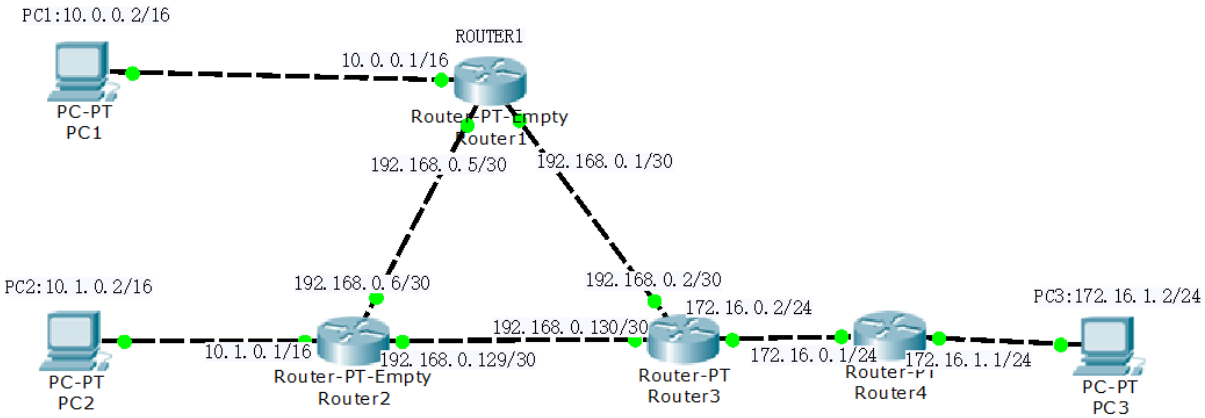
R4:

```
interface FastEthernet0/0
 ip address 172.16.0.1 255.255.255.0
 duplex auto
 speed auto
!
interface FastEthernet1/0
 ip address 172.16.1.1 255.255.255.0
 duplex auto
 speed auto
!
interface Serial2/0
 no ip address
 shutdown
!
interface Serial3/0
 no ip address
 shutdown
!
interface FastEthernet4/0
 no ip address
 shutdown
!
interface FastEthernet5/0
 no ip address
 shutdown
!
router ospf 34
 log-adjacency-changes
 network 172.16.0.0 0.0.0.255 area 2
 network 172.16.1.0 0.0.0.255 area 2
!
ip classless
```

详见 txt.

- 记录本部分的最后完整实验拓扑图（标记路由器型号、连接端口、PC 的 IP 地址、路由器各端口的 IP 地址）

(注：由于我在实验中误操作，第二部分后半段实验的拓扑是重新搭建的，因此在可能形态和部分非关键参数方面（如环路地址，路由器名称）和第一部分的有所不同)



六、 实验结果与分析

- 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，可以不相同，因为进程号是路由器的内置属性。但原则上不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：如果没有配置，会从所有接口中选择最大的一个作为 router ID；如果配置了，则会优先选择回环接口作为 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？

  答：以 R2 为例，原来的 id 为 129 接口：

```
Router>
Router>show ip ospf database
            OSPF Router with ID (192.168.0.129) (Process ID 34)

                Router Link States (Area 0)
```

现在关闭这个接口，再检查：

```
Router#show ip ospf database
            OSPF Router with ID (192.168.0.129) (Process ID 34)

                Router Link States (Area 0)
```

发现没有变。

重启路由器：

```
Router>
Router>
Router>show ip ospf database
            OSPF Router with ID (192.168.0.129) (Process ID 34)

                Router Link States (Area 0)
```

发现没有变。

彻底删除链接，清除配置，重启路由器，再检查

```
Router>show ip ospf database
            OSPF Router with ID (192.168.0.129) (Process ID 34)

                Router Link States (Area 0)

Link ID         ADV Router      Age         Seq#       Checksum Link count
192.168.0.129   192.168.0.129   13          0x80000003 0x009457 2
```

发现还是没有变。说明路由器不会自动选择。

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

  答：反掩码就是通配符掩码 ， 通过标记 0 和 1 告诉设备应该匹配到哪位。 在反掩码中，相应位为 1 的地址在比较中忽略，为 0 的必须被检查。IP 地址与反掩码都是 32 位的数 由于跟子网掩码刚好相反，所以也叫反掩码。 例如掩码是 255.255.255.0 ， wildcard-mask 就是 0.0.0.255 ， 255.255.255.248 ， 反掩码就是 0.0.0.7。

- 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：OSPF 在区域间传递 LSA 信息不是链路状态信息，而是纯粹的路由，此时是基于 D-V 算法，不再是链路状态算法，这时就 出现一个问题，路由自环，解决方法是所有 ABR 将本区域内的路由信息封装成 LSA 后，统一发给一个特定的区域-骨干区域，再由骨干区域转发给其它区域。骨干区域的任务就是汇总每一个区域的网络拓扑到其他的区域。所有的区域间的通信都必须通过骨干区域，非骨干区域间不能通信，所以就不会产生路由自环了。

  Virtual-link 就是为了解决 OSPF 骨干区域 Area 0 不连续的问题而设计的。OSPF 协议定了骨干区域 Area 0，并规定所有非骨干区域必须和骨干区域相连。但是在某些特定的情况下，Area 0 并不总是连续的。比如两个公司进行合并后，每个公司都有原来自己的 Area 0,为在过渡阶段保证两个公司合并后网络的可用性，就可能需要用到 Virtual-link 这种技术将两个或多个连续的 Area 0 连接起来，构成一个完整的 OSPF 路由域。

- 为什么要在区域边界路由器上进行路由合并？

  答：可以减少路由表的表项。

七、 讨论、心得

实验过程中遇到的困难，得到的经验教训，对本实验安排的更好建议（看完请删除本句）

本实验的量依然较大，不过有了实验 5 的经验，这次我的完成情况还是很不错的，为此我十分高兴。

通过本次实验，我了解了 OSPF 的基本原理，并应用了解到的原理进行了基于 OSPF 的组网，更加深入地学习了网络层的相关知识。为今后的实验和期末考试打下了良好的基础。

本次实验中，我主要遇到的问题是在划分 area 的过程中所遇到的 area 不匹配错误和对反掩码的不理解导致的配置错误，以至于我在整个实验过程中重新搭建了两次网络拓扑，甚至更换了 PT 软件的版本，以致于前后两个部分网络拓扑中的实验数据也存在细微的出入（好在并不影响实验结果）。克服以上困难的过程，锻炼了我的能力和心态，也让我收获了更多知识，我想这就是本次实验的价值所在吧。