第二章 OSPF协议特性与配置

实验 2-1 OSPF 单区域

学习目的

- 掌握单区域OSPF的配置方法
- 掌握OSPF区域认证的配置方法
- 了解OSPF在多路访问网络邻居关系建立的过程
- 理解OSPF对Loopback接口所连接网络的掩码发布的形式
- 掌握对OSPF接口代价值进行修改的方法
- 掌握OSPF中Silent-interface的配置方法
- 掌握使用Display查看OSPF各种状态的方法
- 掌握使用Debug命令查看OSPF邻接关系和进行故障排除的方法

拓扑图

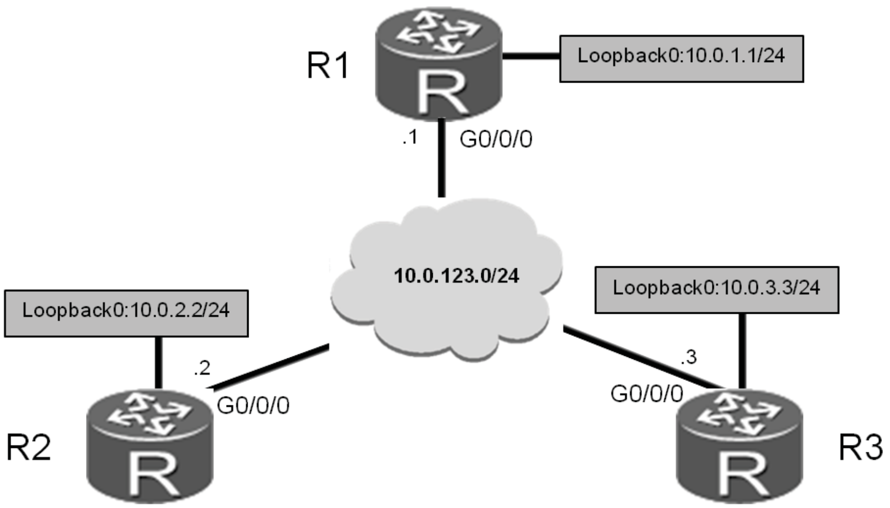


图2-1 OSPF单区域

场景

你是公司的网络管理员。现在公司的网络中有三台ARG3路由器，通过以太网实现相互的连通。在以太网这样的广播式多路访问网络上，可能存在安全隐患，所有你选择采用OSPF区域认证的方法来避免恶意的路由攻击。在部署网络的过程中，出现了网络连通性的问题，你通过使用**display**和**debug**命令进行了故障排除。

学习任务

步骤一. 基础配置与 IP 编址

给R1、R2和R3配置IP地址和掩码。配置时Loopback接口配置掩码为24位，模拟成一个单独的网段。配置完成后，测试直连链路的连通性。

```
<R1>system-view
Enter system view, return user view with Ctrl+Z.
[R1]interface GigabitEthernet 0/0/0
[R1-GigabitEthernet0/0/0]ip address 10.0.123.1 24
[R1-GigabitEthernet0/0/0]quit
[R1]interface LoopBack 0
[R1-LoopBack0]ip address 10.0.1.1 24
[R1-LoopBack0]quit

<R2>system-view
Enter system view, return user view with Ctrl+Z.
[R2]interface GigabitEthernet 0/0/0
[R2-GigabitEthernet0/0/0]ip address 10.0.123.2 24
[R2-GigabitEthernet0/0/0]quit
[R2]interface LoopBack 0
[R2-LoopBack0]ip address 10.0.2.2 24
[R2-LoopBack0]quit

<R3>system-view
Enter system view, return user view with Ctrl+Z.
[R3]interface GigabitEthernet 0/0/0
[R3-GigabitEthernet0/0/0]ip address 10.0.123.3 24
[R3-GigabitEthernet0/0/0]quit
[R3]interface LoopBack 0
[R3-LoopBack0]ip address 10.0.3.3 24
[R3-LoopBack0]quit
```

配置完各接口地址之后验证路由器之间的连通性。

```
[R1]ping -c 1 10.0.123.2
  PING 10.0.123.2: 56  data bytes, press CTRL_C to break
    Reply from 10.0.123.2: bytes=56 Sequence=1 ttl=255 time=2 ms

  --- 10.0.123.2 ping statistics ---
    1 packet(s) transmitted
    1 packet(s) received
    0.00% packet loss
    round-trip min/avg/max = 2/2/2 ms

[R1]ping -c 1 10.0.123.3
  PING 10.0.123.3: 56  data bytes, press CTRL_C to break
    Reply from 10.0.123.3: bytes=56 Sequence=1 ttl=255 time=2 ms

  --- 10.0.123.3 ping statistics ---
    1 packet(s) transmitted
    1 packet(s) received
    0.00% packet loss
    round-trip min/avg/max = 2/2/2 ms

[R2]ping -c 1 10.0.123.3
  PING 10.0.123.3: 56  data bytes, press CTRL_C to break
    Reply from 10.0.123.3: bytes=56 Sequence=1 ttl=255 time=2 ms

  --- 10.0.123.3 ping statistics ---
    1 packet(s) transmitted
    1 packet(s) received
    0.00% packet loss
    round-trip min/avg/max = 2/2/2 ms
```

步骤二. 配置单区域的 OSPF

配置单区域OSPF。所有路由器属于区域0，配置使用OSPF进程1。同时配置区域认证，使用密码 “huawei ”。在区域中，华为的设备支持使用明文或MD5值进行认证，在这里，我们仅使用明文进行认证。

注意在使用network命令时，通配符掩码使用0.0.0.0。为了保证路由器的Router ID稳定，我们在启动OSPF进程时使用**router-id**参数静态指定路由器的Router ID。

```
[R1]ospf 1 router-id 10.0.1.1
```

```
[R1-ospf-1]area 0
[R1-ospf-1-area-0.0.0.0]network 10.0.123.1 0.0.0.0
[R1-ospf-1-area-0.0.0.0]network 10.0.1.1 0.0.0.0
[R1-ospf-1-area-0.0.0.0]authentication-mode simple plain huawei

[R2]ospf 1 router-id 10.0.2.2
[R2-ospf-1]area 0
[R2-ospf-1-area-0.0.0.0]network 10.0.123.2 0.0.0.0
[R2-ospf-1-area-0.0.0.0]network 10.0.2.2 0.0.0.0
[R2-ospf-1-area-0.0.0.0]authentication-mode simple plain huawei

[R3]ospf 1 router-id 10.0.3.3
[R3-ospf-1]area 0
[R3-ospf-1-area-0.0.0.0]network 10.0.123.3 0.0.0.0
[R3-ospf-1-area-0.0.0.0]network 10.0.3.3 0.0.0.0
[R3-ospf-1-area-0.0.0.0]authentication-mode simple plain huawei
```

配置完成后，查看设备的路由表，并测试全网的连通性。我们首先在R1上查看路由表。

```
[R1]display ip routing-table
Route Flags: R - relay, D - download to fib
------------------------------------------------------------------------------
Routing Tables: Public
         Destinations : 12      Routes : 12

Destination/Mask    Proto  Pre Cost    Flags NextHop        Interface

      10.0.1.0/24   Direct  0    0        D  10.0.1.1       LoopBack0
      10.0.1.1/32   Direct  0    0        D  127.0.0.1      InLoopBack0
    10.0.1.255/32   Direct  0    0        D  127.0.0.1      InLoopBack0
      10.0.2.2/32   OSPF    10   1        D  10.0.123.2     GigabitEthernet0/0/0
      10.0.3.3/32   OSPF    10   1        D  10.0.123.3     GigabitEthernet0/0/0
    10.0.123.0/24   Direct  0    0        D  10.0.123.1     GigabitEthernet0/0/0
    10.0.123.1/32   Direct  0    0        D  127.0.0.1      InLoopBack0
  10.0.123.255/32   Direct  0    0        D  127.0.0.1      InLoopBack0
     127.0.0.0/8    Direct  0    0        D  127.0.0.1      InLoopBack0
     127.0.0.1/32   Direct  0    0        D  127.0.0.1      InLoopBack0
127.255.255.255/32  Direct  0    0        D  127.0.0.1      InLoopBack0
255.255.255.255/32  Direct  0    0        D  127.0.0.1      InLoopBack0
```

从输出中我们可以看到R1从OSPF学习到了2条路由，10.0.2.2/32和10.0.3.3/32，下一跳分别是10.0.123.2和10.0.123.3。然后分别检查从R1到达R2及R3的Loopback地址的连通性。

```
[R1]ping -c 1 10.0.2.2
  PING 10.0.2.2: 56  data bytes, press CTRL_C to break
    Reply from 10.0.2.2: bytes=56 Sequence=1 ttl=255 time=3 ms

  --- 10.0.2.2 ping statistics ---
    1 packet(s) transmitted
    1 packet(s) received
    0.00% packet loss
    round-trip min/avg/max = 3/3/3 ms

[R1]ping -c 1 10.0.3.3
  PING 10.0.3.3: 56  data bytes, press CTRL_C to break
    Reply from 10.0.3.3: bytes=56 Sequence=1 ttl=255 time=2 ms

  --- 10.0.3.3 ping statistics ---
    1 packet(s) transmitted
    1 packet(s) received
    0.00% packet loss
    round-trip min/avg/max = 2/2/2 ms
```

使用display ospf brief命令查看路由器运行的基本OSPF信息。

```
[R1]display ospf brief

         OSPF Process 1 with Router ID 10.0.1.1
                 OSPF Protocol Information

 RouterID: 10.0.1.1        Border Router:
 Multi-VPN-Instance is not enabled
 Global DS-TE Mode: Non-Standard IETF Mode
 Graceful-restart capability: disabled
 Helper support capability  : not configured
 Spf-schedule-interval: max 10000ms, start 500ms, hold 1000ms
 Default ASE parameters: Metric: 1 Tag: 1 Type: 2
 Route Preference: 10
 ASE Route Preference: 150
 SPF Computation Count: 18
 RFC 1583 Compatible
 Retransmission limitation is disabled
 Area Count: 1   Nssa Area Count: 0
 ExChange/Loading Neighbors: 0

 Area: 0.0.0.0
 Authtype: Simple   Area flag: Normal
```

```
SPF scheduled Count: 18
ExChange/Loading Neighbors: 0

Interface: 10.0.123.1 (GigabitEthernet0/0/0)
Cost: 1       State: DROther     Type: Broadcast    MTU: 1500
Priority: 1
Designated Router: 10.0.123.2
Backup Designated Router: 10.0.123.3
Timers: Hello 10 , Dead 40 , Poll  120 , Retransmit 5 , Transmit Delay 1

Interface: 10.0.1.1 (LoopBack0)
Cost: 0       State: P-2-P      Type: P2P      MTU: 1500
Timers: Hello 10 , Dead 40 , Poll  120 , Retransmit 5 , Transmit Delay 1
```

从上面的输出中我们可以看到区域0开启了明文认证(Authtype: Simple)，共有两个接口参加了OSPF的运行 :GigabitEthernet0/0/0和LoopBack0。其中，GigabitEthernet0/0/0为广播型网络（Broadcast），开销（Cost）为1，优先级（Priority）为1，R1自己的角色为DROther，后面列出了该网络上的DR（10.0.123.2）和BDR（10.0.123.3）。另外一个运行OSPF的接口LoopBack0的网络类型为P2P。

使用display ospf peer brief命令查看路由器的OSPF邻居关系建立情况。

```
[R1]display ospf peer brief

       OSPF Process 1 with Router ID 10.0.1.1
              Peer Statistic Information
 ----------------------------------------------------------------------------
 Area Id          Interface                    Neighbor id      State
 0.0.0.0          GigabitEthernet0/0/0           10.0.2.2         Full
 0.0.0.0          GigabitEthernet0/0/0           10.0.3.3         Full
 ----------------------------------------------------------------------------
```

从上面的输出中我们可以看到在区域0.0.0.0中，R1有两个邻居，邻居的Router ID分别为10.0.2.2和10.0.3.3，他们之间的状态为Full。

使用display ospf lsdb命令查看路由器的OSPF数据库信息。

```
[R1]dis ospf lsdb

       OSPF Process 1 with Router ID 10.0.1.1
             Link State Database


                    Area: 0.0.0.0
 Type      LinkState ID     AdvRouter          Age  Len   Sequence   Metric
```

```
Router    10.0.3.3        10.0.3.3         98  48    80000011      1
Router    10.0.2.2        10.0.2.2         98  48    80000016      1
Router    10.0.1.1        10.0.1.1         96  48    80000013      1
Network   10.0.123.2      10.0.2.2         99  36    8000000F      0
```

在这里我们一共可以看到4条LSA，前3条为第一类LSA，分别由R1、R2和R3产生，我们可以通过AdvRouter判断该LSA是由哪台路由器生成的。第四条为第二类LSA，是由一个网段的DR产生的。在这里，R2是10.0.123.0/24这个网段的DR，所以我们可以看到这条LSA的AdvRouter为10.0.2.2。

```
[R1]display ospf lsdb router self-originate

       OSPF Process 1 with Router ID 10.0.1.1
                     Area: 0.0.0.0
              Link State Database


  Type      : Router
  Ls id     : 10.0.1.1
  Adv rtr    : 10.0.1.1
  Ls age    : 680
  Len       : 48
  Options    :  E
  seq#      : 80000013
  chksum    : 0x7787
  Link count: 2
   * Link ID: 10.0.123.2
     Data   : 10.0.123.1
     Link Type: TransNet
     Metric : 1
   * Link ID: 10.0.1.1
     Data   : 255.255.255.255
     Link Type: StubNet
     Metric : 0
     Priority : Medium
```

上面的输出是R1产生的Router LSA的详细信息，我们可以看到这条LSA一共描述了2个网络，第一个网络为三台路由器的互联网段，链路类型为TransNet，可以看到Link ID为DR的端口地址10.0.123.2，Data为该网段上本地端口的IP地址10.0.123.1；另一个网络为Loopback接口所在网段，链路类型为StubNet，Link ID和Data分别是该Stub网段的IP地址和掩码。

```
[R2]dis ospf lsdb network self-originate

       OSPF Process 1 with Router ID 10.0.2.2
```

```
                  Area: 0.0.0.0
            Link State Database

 Type      : Network
 Ls id     : 10.0.123.2
 Adv rtr   : 10.0.2.2
 Ls age    : 1369
 Len       : 36
 Options   :  E
 seq#      : 8000000f
 chksum    : 0xa7e
 Net mask  : 255.255.255.0
 Priority  : Low
   Attached Router    10.0.2.2
   Attached Router    10.0.1.1
   Attached Router    10.0.3.3
```

上面的输出是R2产生的Network LSA的详细信息，我们可以看到第二类LSA描述了DR所在网段的邻居信息。

步骤三. 观察路由器在以太网上邻接关系的建立过程

首先查看在10.0.123.0/24网段，OSPF邻居关系中DR和BDR选举的情况，并分析为什么会这样？以及是否所有人在做这个实验时，结果都是一样的。

我们首先查看在10.0.123.0/24网段，OSPF邻居关系中DR和BDR选举的情况。从下面的输出中，我们可以得知现在该网段的DR的接口IP为10.0.123.2，BDR的接口IP为10.0.123.3。

```
[R1]display ospf peer

       OSPF Process 1 with Router ID 10.0.1.1
             Neighbors

 Area 0.0.0.0 interface 10.0.123.1(GigabitEthernet0/0/0)'s neighbors
 Router ID: 10.0.2.2        Address: 10.0.123.2
   State: Full  Mode:Nbr is  Master  Priority: 1
   DR: 10.0.123.2  BDR: 10.0.123.3  MTU: 0
   Dead timer due in 40  sec
   Retrans timer interval: 5
   Neighbor is up for 00:32:27
   Authentication Sequence: [ 0 ]
```

```
 Router ID: 10.0.3.3        Address: 10.0.123.3
   State: Full  Mode:Nbr is  Master  Priority: 1
   DR: 10.0.123.2  BDR: 10.0.123.3  MTU: 0
   Dead timer due in 33  sec
   Retrans timer interval: 3
   Neighbor is up for 00:32:28
   Authentication Sequence: [ 0 ]
```

有可能每个人得实验结果输出不一样。因为在OSPF中，DR的选举不是抢占的，即网络中存在DR或BDR时，新进入网络的路由器不能抢占DR或BDR的角色。在这个网络中，先启动OSPF进程或先接入该网络的路由器成为了该网段上的DR，其他路由器成为的BDR或DROther。

当DR发生故障后，BDR就会接替DR的位置，我们在实验中可以通过重置OSPF进程的方法来观察DR角色的改变，在这里，我们重置R2的OSPF进程。

```
<R2>reset ospf process
Warning: The OSPF process will be reset. Continue? [Y/N]:y

[R2]display ospf peer

        OSPF Process 1 with Router ID 10.0.2.2
               Neighbors

 Area 0.0.0.0 interface 10.0.123.2(GigabitEthernet0/0/0)'s neighbors
 Router ID: 10.0.1.1        Address: 10.0.123.1
   State: Full  Mode:Nbr is  Slave  Priority: 1
   DR: 10.0.123.3  BDR: 10.0.123.1  MTU: 0
   Dead timer due in 33  sec
   Retrans timer interval: 4
   Neighbor is up for 00:00:35
   Authentication Sequence: [ 0 ]

 Router ID: 10.0.3.3        Address: 10.0.123.3
   State: Full  Mode:Nbr is  Master  Priority: 1
   DR: 10.0.123.3  BDR: 10.0.123.1  MTU: 0
   Dead timer due in 33  sec
   Retrans timer interval: 5
   Neighbor is up for 00:00:35
   Authentication Sequence: [ 0 ]
```

当重置R2的OSPF进程以后，原来该网络上的BDR 10.0.123.3成为了新的DR，原来的DROther 10.0.123.1成为了新的BDR。

下面我们关闭R1、R2与R3的G0/0/0接口，使用命令**debugging ospf 1 event**准备查看OSPF邻接关系建立的具体过程。然后尽量同时打开R1、R2与R3的G0/0/0接口。观察在广播式多路访问网络上邻居状态的变化过程和DR和BDR选举的过程。

```
<R1>debugging ospf 1 event
<R1>terminal debugging
[R1]int GigabitEthernet 0/0/0
[R1-GigabitEthernet0/0/0]shut
[R1-GigabitEthernet0/0/0]undo shut
```

在R2和R3上进行相同的操作，查看R3的debug信息。由于所有路由器默认的接口优先级都是1，所以在DR选举的时候会参考路由器的Router ID，在这三台路由器中，R3的Router ID是最大的，所以R3成为了该网段上的DR。

```
[R3-GigabitEthernet0/0/0]undo shutdown
Nov 22 2011 18:41:50.990.3+00:00 R3 RM/6/RMDEBUG:
 FileID: 0xd017802c Line: 1268 Level: 0x20
  OSPF 1: Intf 10.0.123.3 Rcv InterfaceUp State Down -> Waiting.
Nov 22 2011 18:41:50.990.4+00:00 R3 RM/6/RMDEBUG:
 FileID: 0xd017802c Line: 1382 Level: 0x20
  OSPF 1 Send Hello Interface Up on 10.0.123.3
Nov 22 2011 18:41:57.470.1+00:00 R3 RM/6/RMDEBUG:
 FileID: 0xd017802d Line: 1132 Level: 0x20
  OSPF 1: Nbr 10.0.123.1 Rcv HelloReceived State Down -> Init.
Nov 22 2011 18:41:57.480.1+00:00 R3 RM/6/RMDEBUG:
 FileID: 0xd017802d Line: 1728 Level: 0x20
  OSPF 1: Nbr 10.0.123.1 Rcv 2WayReceived State Init -> 2Way.
Nov 22 2011 18:41:59.510.3+00:00 R3 RM/6/RMDEBUG:
 FileID: 0xd017802d Line: 1132 Level: 0x20
  OSPF 1: Nbr 10.0.123.2 Rcv HelloReceived State Down -> Init.
Nov 22 2011 18:41:59.510.4+00:00 R3 RM/6/RMDEBUG:
 FileID: 0xd017802d Line: 1728 Level: 0x20
  OSPF 1: Nbr 10.0.123.2 Rcv 2WayReceived State Init -> 2Way.
Nov 22 2011 18:42:28.350.4+00:00 R3 RM/6/RMDEBUG:
 FileID: 0xd017802d Line: 1728 Level: 0x20
  OSPF 1: Nbr 10.0.123.1 Rcv AdjOk? State 2Way -> ExStart.
Nov 22 2011 18:42:28.350.5+00:00 R3 RM/6/RMDEBUG:
 FileID: 0xd017802d Line: 1728 Level: 0x20
  OSPF 1: Nbr 10.0.123.2 Rcv AdjOk? State 2Way -> ExStart.
Nov 22 2011 18:42:28.350.6+00:00 R3 RM/6/RMDEBUG:
 FileID: 0xd017802c Line: 2045 Level: 0x20
  OSPF 1 Send Hello Interface State Changed on 10.0.123.3
Nov 22 2011 18:42:28.350.7+00:00 R3 RM/6/RMDEBUG:
```

```
FileID: 0xd017802c Line: 2056 Level: 0x20
 OSPF 1: Intf 10.0.123.3 Rcv WaitTimer State Waiting -> DR.
```

当刚打开接口时，接口状态由Down变为Waiting，此时路由器开始交互Hello数据包，等待约40秒以后，R3的接口由Waiting变为DR。

步骤四. 配置 OSPF 中 Loopback 接口的网络类型

观察R1的路由表，关注这两条路由：10.0.2.2/32和10.0.3.3/32。

```
[R1]display ip routing-table
Route Flags: R - relay, D - download to fib
------------------------------------------------------------------------------
Routing Tables: Public
        Destinations : 12      Routes : 12

Destination/Mask    Proto  Pre Cost    Flags NextHop        Interface

      10.0.1.0/24   Direct  0    0        D  10.0.1.1       LoopBack0
      10.0.1.1/32   Direct  0    0        D  127.0.0.1      InLoopBack0
    10.0.1.255/32   Direct  0    0        D  127.0.0.1      InLoopBack0
      10.0.2.2/32   OSPF    10   1        D  10.0.123.2     GigabitEthernet0/0/0
      10.0.3.3/32   OSPF    10   1        D  10.0.123.3     GigabitEthernet0/0/0
    10.0.123.0/24   Direct  0    0        D  10.0.123.1     GigabitEthernet0/0/0
    10.0.123.1/32   Direct  0    0        D  127.0.0.1      InLoopBack0
  10.0.123.255/32   Direct  0    0        D  127.0.0.1      InLoopBack0
     127.0.0.0/8    Direct  0    0        D  127.0.0.1      InLoopBack0
     127.0.0.1/32   Direct  0    0        D  127.0.0.1      InLoopBack0
127.255.255.255/32  Direct  0    0        D  127.0.0.1      InLoopBack0
255.255.255.255/32  Direct  0    0        D  127.0.0.1      InLoopBack0
```

在配置R2和R3的Loopback接口地址时，使用的掩码是24位，分析为什么这里为什么路由表中显示的是32位掩码的路由？

使用命令**display ospf interface LoopBack 0 verbose**查看OSPF在Loopback 0接口运行的状态信息。

```
[R1]display ospf interface LoopBack 0 verbose

        OSPF Process 1 with Router ID 10.0.1.1
                Interfaces


 Interface: 10.0.1.1 (LoopBack0)
```

```
 Cost: 0      State: P-2-P     Type: P2P      MTU: 1500
 Timers: Hello 10 , Dead 40 , Poll  120 , Retransmit 5 , Transmit Delay 1
  IO Statistics
           Type       Input     Output
          Hello         0          0
   DB Description       0          0
   Link-State Req       0          0
Link-State Update       0          0
   Link-State Ack       0          0
 ALLSPF GROUP
 OpaqueId: 0   PrevState: Down
```

可以看到对于Loopback接口，OSPF知道该网段只可能有一个IP地址，所以发布的路由的子网掩码是32位的。

修改R2的Loopback0接口的网络类型为Broadcast，OSPF在发布这个接口的网络信息时，就会使用24位掩码进行发布。

```
[R2]interface LoopBack 0
[R2-LoopBack0]ospf network-type broadcast
```

这时我们看到R2发布的Loopback 0地址的路由子网掩码为24位。

```
[R1]display ip routing-table
Route Flags: R - relay, D - download to fib
------------------------------------------------------------------------------
Routing Tables: Public
         Destinations : 12      Routes : 12

Destination/Mask    Proto  Pre Cost    Flags NextHop        Interface

      10.0.1.0/24   Direct  0   0        D  10.0.1.1       LoopBack0
      10.0.1.1/32   Direct  0   0        D  127.0.0.1       InLoopBack0
    10.0.1.255/32   Direct  0   0        D  127.0.0.1       InLoopBack0
      10.0.2.0/24   OSPF   10   1        D  10.0.123.2     GigabitEthernet0/0/0
      10.0.3.3/32   OSPF   10   1        D  10.0.123.3     GigabitEthernet0/0/0
    10.0.123.0/24   Direct  0   0        D  10.0.123.1     GigabitEthernet0/0/0
    10.0.123.1/32   Direct  0   0        D  127.0.0.1       InLoopBack0
  10.0.123.255/32   Direct  0   0        D  127.0.0.1       InLoopBack0
     127.0.0.0/8    Direct  0   0        D  127.0.0.1       InLoopBack0
     127.0.0.1/32   Direct  0   0        D  127.0.0.1       InLoopBack0
127.255.255.255/32  Direct  0   0        D  127.0.0.1       InLoopBack0
255.255.255.255/32  Direct  0   0        D  127.0.0.1       InLoopBack0
```

使用命令**display ospf interface LoopBack 0 verbose**查看Loopback接口的运行状态可以看到，该接口网络类型为Broadcast。

```
[R2]display ospf interface LoopBack 0 verbose

        OSPF Process 1 with Router ID 10.0.2.2
               Interfaces


 Interface: 10.0.2.2 (LoopBack0)
 Cost: 0      State: DR       Type: Broadcast    MTU: 1500
 Priority: 1
 Designated Router: 10.0.2.2
 Backup Designated Router: 0.0.0.0
 Timers: Hello 10 , Dead 40 , Poll  120 , Retransmit 5 , Transmit Delay 1
  IO Statistics
          Type       Input     Output
         Hello         0         0
  DB Description       0         0
  Link-State Req       0         0
Link-State Update      0         0
  Link-State Ack       0         0
 ALLSPF GROUP
 ALLDR GROUP
 OpaqueId: 0   PrevState: Waiting
```

步骤五.　修改接口的 OSPF 代价值

首先在R1上查看R1到达R3的Loopback0接口路由的代价值，我们可以看到到达10.0.3.3/32的代价值为1。

```
[R1]display ip routing-table
Route Flags: R - relay, D - download to fib
------------------------------------------------------------------------------
Routing Tables: Public
        Destinations : 12      Routes : 12

Destination/Mask    Proto  Pre Cost    Flags NextHop        Interface

      10.0.1.0/24   Direct  0    0       D   10.0.1.1       LoopBack0
      10.0.1.1/32   Direct  0    0       D   127.0.0.1       InLoopBack0
    10.0.1.255/32   Direct  0    0       D   127.0.0.1       InLoopBack0
```

```
      10.0.2.0/24   OSPF    10   1        D   10.0.123.2     GigabitEthernet0/0/0
      10.0.3.3/32   OSPF    10   1        D   10.0.123.3     GigabitEthernet0/0/0
    10.0.123.0/24   Direct  0    0        D   10.0.123.1     GigabitEthernet0/0/0
    10.0.123.1/32   Direct  0    0        D   127.0.0.1       InLoopBack0
  10.0.123.255/32   Direct  0    0        D   127.0.0.1       InLoopBack0
     127.0.0.0/8    Direct  0    0        D   127.0.0.1       InLoopBack0
     127.0.0.1/32   Direct  0    0        D   127.0.0.1       InLoopBack0
127.255.255.255/32  Direct  0    0        D   127.0.0.1       InLoopBack0
255.255.255.255/32  Direct  0    0        D   127.0.0.1       InLoopBack0
```

修改R1的G0/0/0接口代价值为20，修改R3的G0/0/0接口代价值为10。

```
[R1]interface GigabitEthernet 0/0/0
[R1-GigabitEthernet0/0/0]ospf cost 20

[R3]interface GigabitEthernet 0/0/0
[R3-GigabitEthernet0/0/0]ospf cost 10
```

重新查看R1到达R3的Loopback0接口路由的代价值，可以看到，到达10.0.3.3/32的代价值为20。

```
[R1]display ip routing-table
Route Flags: R - relay, D - download to fib
------------------------------------------------------------------------------
Routing Tables: Public
        Destinations : 12       Routes : 12

Destination/Mask    Proto  Pre Cost    Flags NextHop        Interface

      10.0.1.0/24   Direct  0    0        D   10.0.1.1       LoopBack0
      10.0.1.1/32   Direct  0    0        D   127.0.0.1       InLoopBack0
    10.0.1.255/32   Direct  0    0        D   127.0.0.1       InLoopBack0
      10.0.2.0/24   OSPF    10   20       D   10.0.123.2     GigabitEthernet0/0/0
      10.0.3.3/32   OSPF    10   20       D   10.0.123.3     GigabitEthernet0/0/0
    10.0.123.0/24   Direct  0    0        D   10.0.123.1     GigabitEthernet0/0/0
    10.0.123.1/32   Direct  0    0        D   127.0.0.1       InLoopBack0
  10.0.123.255/32   Direct  0    0        D   127.0.0.1       InLoopBack0
     127.0.0.0/8    Direct  0    0        D   127.0.0.1       InLoopBack0
     127.0.0.1/32   Direct  0    0        D   127.0.0.1       InLoopBack0
127.255.255.255/32  Direct  0    0        D   127.0.0.1       InLoopBack0
255.255.255.255/32  Direct  0    0        D   127.0.0.1       InLoopBack0
```

在R3上查看10.0.1.1/32的代价值，可以看到值为10。

```
[R3]display ip routing-table
```

```
Route Flags: R - relay, D - download to fib
------------------------------------------------------------------------------
Routing Tables: Public
        Destinations : 12       Routes : 12

Destination/Mask    Proto  Pre  Cost    Flags NextHop         Interface

      10.0.1.1/32   OSPF    10   10       D   10.0.123.1     GigabitEthernet0/0/0
      10.0.2.0/24   OSPF    10   10       D   10.0.123.2     GigabitEthernet0/0/0
      10.0.3.0/24   Direct  0    0        D   10.0.3.3        LoopBack0
      10.0.3.3/32   Direct  0    0        D   127.0.0.1       InLoopBack0
    10.0.3.255/32   Direct  0    0        D   127.0.0.1       InLoopBack0
    10.0.123.0/24   Direct  0    0        D   10.0.123.3     GigabitEthernet0/0/0
    10.0.123.3/32   Direct  0    0        D   127.0.0.1       InLoopBack0
  10.0.123.255/32   Direct  0    0        D   127.0.0.1       InLoopBack0
     127.0.0.0/8    Direct  0    0        D   127.0.0.1       InLoopBack0
     127.0.0.1/32   Direct  0    0        D   127.0.0.1       InLoopBack0
127.255.255.255/32  Direct  0    0        D   127.0.0.1       InLoopBack0
255.255.255.255/32  Direct  0    0        D   127.0.0.1       InLoopBack0
```

在华为中称为silent-interface,在Cisco中称为passive-interface。

步骤六.　配置 OSPF 的 Silent-interface

配置R1的G0/0/0接口为Silent-interface。

```
[R1]ospf 1
[R1-ospf-1]silent-interface GigabitEthernet 0/0/0
```

查看R1的邻居关系建立和路由表学习情况可发现，路由表中从OSPF学习到的路由条目消失了。

```
[R1]display ip routing-table
Route Flags: R - relay, D - download to fib
------------------------------------------------------------------------------
Routing Tables: Public
        Destinations : 12       Routes : 12

Destination/Mask    Proto  Pre Cost     Flags NextHop         Interface

      10.0.1.0/24   Direct  0    0        D   10.0.1.1        LoopBack0
      10.0.1.1/32   Direct  0    0        D   127.0.0.1       InLoopBack0
    10.0.1.255/32   Direct  0    0        D   127.0.0.1       InLoopBack0
    10.0.123.0/24   Direct  0    0        D   10.0.123.1     GigabitEthernet0/0/0
```

```
    10.0.123.1/32  Direct  0    0       D   127.0.0.1      InLoopBack0
  10.0.123.255/32  Direct  0    0       D   127.0.0.1      InLoopBack0
     127.0.0.0/8   Direct  0    0       D   127.0.0.1      InLoopBack0
     127.0.0.1/32  Direct  0    0       D   127.0.0.1      InLoopBack0
127.255.255.255/32 Direct  0    0       D   127.0.0.1      InLoopBack0
255.255.255.255/32 Direct  0    0       D   127.0.0.1      InLoopBack0
```

查看R1的邻居列表可以看到R1和R2、R3之间的邻居关系也消失了。在RIP中将一个接口置为Silent-interface以后，该接口不再发送RIP更新；但在OSPF中，路由器之间需要建立邻居关系之后才会交互路由信息，当一个接口被设置为Silent-interface以后，该接口不再接收或发送Hello包，造成该接口不能和其他路由器形成邻居关系。

```
[R1]display ospf interface GigabitEthernet 0/0/0

        OSPF Process 1 with Router ID 10.0.1.1
                Interfaces



 Interface: 10.0.123.1 (GigabitEthernet0/0/0)
 Cost: 20     State: DR       Type: Broadcast    MTU: 1500
 Priority: 10
 Designated Router: 10.0.123.1
 Backup Designated Router: 0.0.0.0
 Timers: Hello 10 , Dead 40 , Poll  120 , Retransmit 5 , Transmit Delay 1
 Silent interface, No hellos
```

使用**debugging ip packet**调试路由器接收到的数据包观察OSPF报文的接收情况，可以看到路由器接收到一个OSPF报文（protocol = 89）以后将该报文丢弃了。

```
<R1>debugging ip packet
Nov 23 2011 09:51:53.500.1+00:00 R1 IP/7/debug_case:
Receiving, interface = GE0/0/0, version = 4, headlen = 20, tos = 192,
pktlen = 68, pktid = 7272, offset = 0, ttl = 1, protocol = 89,
checksum = 14129, s = 10.0.123.3, d = 224.0.0.5
prompt: Receiving IP packet from GE0/0/0


Nov 23 2011 09:51:53.500.2+00:00 R1 IP/7/debug_case:
Receiving, interface = GigabitEthernet0/0/0, version = 4, headlen = 20, tos =
192,
pktlen = 68, pktid = 7272, offset = 0, ttl = 1, protocol = 89,
checksum = 14129, s = 10.0.123.3, d = 224.0.0.5
```

```
prompt: IP_ProcessByBoard Begin!


Nov 23 2011 09:51:53.500.3+00:00 R1 IP/7/debug_case:
Discarding, interface = GE0/0/0, version = 4, headlen = 20, tos = 192,
pktlen = 68, pktid = 7272, offset = 0, ttl = 1, protocol = 89,
checksum = 14129, s = 10.0.123.3, d = 224.0.0.5
prompt: IP_Distribute: The packet was dropped by security application.
```

恢复R1的G0/0/0接口为默认状态，将三个路由器的Loopback0接口配置为Silent-interface。

```
[R1]ospf 1
[R1-ospf-1]undo silent-interface GigabitEthernet0/0/0
[R1-ospf-1]silent-interface LoopBack 0

[R2]ospf 1
[R2-ospf-1]silent-interface LoopBack 0

[R3]ospf 1
[R3-ospf-1]silent-interface LoopBack 0
```

检查R1的路由表可见，将Loopback设为Silent-interface以后不影响该接口路由的发布。

```
[R1]display ip routing-table
Route Flags: R - relay, D - download to fib
------------------------------------------------------------------------------
Routing Tables: Public
        Destinations : 12      Routes : 12

Destination/Mask    Proto  Pre Cost    Flags NextHop        Interface

      10.0.1.0/24   Direct  0    0       D   10.0.1.1       LoopBack0
      10.0.1.1/32   Direct  0    0       D   127.0.0.1      InLoopBack0
    10.0.1.255/32   Direct  0    0       D   127.0.0.1      InLoopBack0
      10.0.2.2/24   OSPF    10   20      D   10.0.123.2     GigabitEthernet0/0/0
      10.0.3.3/32   OSPF    10   20      D   10.0.123.3     GigabitEthernet0/0/0
    10.0.123.0/24   Direct  0    0       D   10.0.123.1     GigabitEthernet0/0/0
    10.0.123.1/32   Direct  0    0       D   127.0.0.1      InLoopBack0
  10.0.123.255/32   Direct  0    0       D   127.0.0.1      InLoopBack0
     127.0.0.0/8    Direct  0    0       D   127.0.0.1      InLoopBack0
     127.0.0.1/32   Direct  0    0       D   127.0.0.1      InLoopBack0
127.255.255.255/32  Direct  0    0       D   127.0.0.1      InLoopBack0
```

附加实验：思考并验证

为什么在配置OSPF时，使用的通配符掩码是0.0.0.0，实际的配置中，也可以使用通配符掩码0.0.0.255，思考一下，这两种表达形式有什么差异？

分析在实际的网络中，哪些类型的接口应该配置为Silent-interface接口？

最终设备配置

```
<R1>display current-configuration
[V200R001C00SPC200]
#
 sysname R1
#
interface GigabitEthernet0/0/0
 ip address 10.0.123.1 255.255.255.0
 ospf cost 20
#
interface LoopBack0
 ip address 10.0.1.1 255.255.255.0
#
ospf 1 router-id 10.0.1.1
 silent-interface LoopBack0
 area 0.0.0.0
  authentication-mode simple plain huawei
  network 10.0.123.1 0.0.0.0
  network 10.0.1.1 0.0.0.0
#
return
```

```
<R2>display current-configuration
[V200R001C00SPC200]
#
 sysname R2
#
interface GigabitEthernet0/0/0
 ip address 10.0.123.2 255.255.255.0
#
interface LoopBack0
```

```
 ip address 10.0.2.2 255.255.255.0
 ospf network-type broadcast
#
ospf 1 router-id 10.0.2.2
 silent-interface LoopBack0
 area 0.0.0.0
  authentication-mode simple plain huawei
  network 10.0.123.2 0.0.0.0
  network 10.0.2.2 0.0.0.0
#
return

<R3>display current-configuration
[V200R001C00SPC200]
#
 sysname R3
#
interface GigabitEthernet0/0/0
 ip address 10.0.123.3 255.255.255.0
 ospf cost 10
#
interface LoopBack0
 ip address 10.0.3.3 255.255.255.0
#
ospf 1 router-id 10.0.3.3
 silent-interface LoopBack0
 area 0.0.0.0
  authentication-mode simple plain huawei
  network 10.0.123.3 0.0.0.0
  network 10.0.3.3 0.0.0.0
#
return
```

实验 2-2 OSPF 多区域

学习目的

- 掌握OSPF配置指定Router ID的方法
- 掌握多区域OSPF的配置方法
- 掌握OSPF区域之间路由汇总的配置方法
- 掌握OSPF参考带宽的配置方法
- 掌握OSPF引入外部路由的配置方法
- 掌握OSPF引入的外部路由时进行路由汇总的方法
- 掌握向OSPF导入缺省路由的方法
- 掌握对OSPF中各类路由的管理距离的修改方法

拓扑图

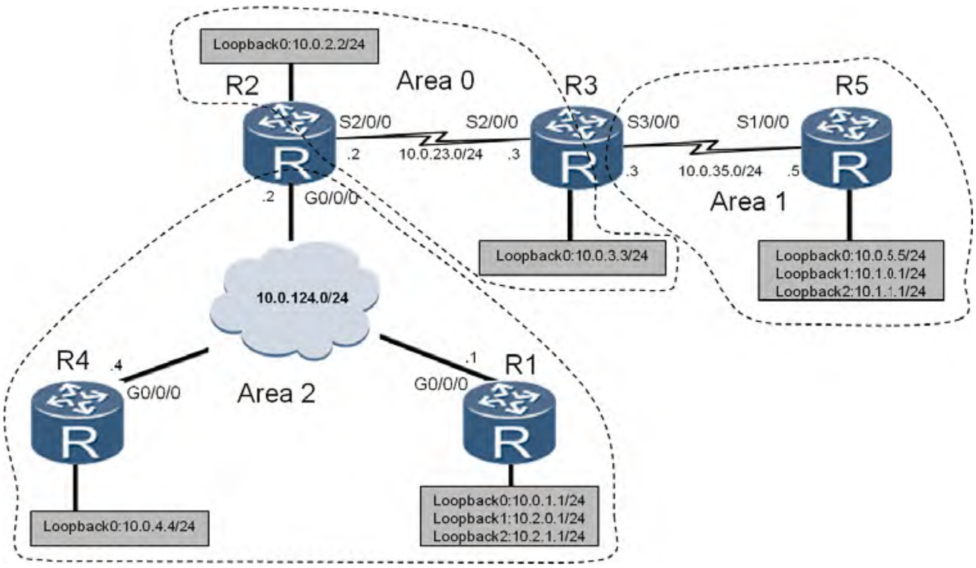


图2-2 OSPF多区域

场景

你是公司的网络管理员。现在公司的网络中有五台ARG3路由器，其中R1、R2和R4在公司总部，通过以太网互联。R3、与R5在公司分部，R3通过专线与公司总部的R2相连，R5与R3之间也通过专项相连。由于网络规模较大，为了控制LSA的洪泛，你设计了多区域的OSPF互联方式。

其中R2与R3的Loopback0接口、互联接口属于区域0 ;R3与R5互联的网段、R5的Loopback0/1/2接口属于区域1；R1、R2与R4互联的网段以及R1、R4的Loopback0接口属于区域2。

同时为了明确设备的Router-ID ,你配置设备使用固定的地址作为Router ID。

为了使路由器进行路由转发时效率更高，在区域的边界你配置了自动汇总。

R1路由器连接到公司以外的网络，你配置将这些OSPF区域之外的路由信息引入到OSPF区域。

R4路由器连接到Internet，你需要配置一条缺省路由，引入到OSPF区域，以便于OSPF区域的所有路由器都知道如何访问Internet。

同时OSPF路由信息中区分了内部路由和外部路由，你修改了OSPF路由信息的优先级信息，以避免潜在的风险。

OSPF中特定路由信息的度量值是将到达目的网络所经过的所有链路的代价值进行累加得到的。而链路的代价值是路由器将接口带宽与参考带宽进行对比得到。参考带宽值为100Mbps，实际接口带宽可能为1000Mbps，而度量值都是整数，所以快速以太网接口和千兆以太网接口的OSPF代价值均为1。为了能够相互区分这些链路，你定义参考带宽值为10Gbps。

在配置设备的同时，出现了一些网络故障，你通过使用display和debug命令进行了故障排除。

学习任务

步骤一. 基础配置与 IP 编址

给所有路由器配置IP地址和掩码。配置时注意所有的Loopback接口配置掩码均为24位，模拟成一个单独的网段。

```
<R1>system-view
Enter system view, return user view with Ctrl+Z.
[R1]interface GigabitEthernet 0/0/0
[R1-GigabitEthernet0/0/0]ip address 10.0.124.1 24
[R1-GigabitEthernet0/0/0]interface LoopBack 0
```

```
[R1-LoopBack0]ip address 10.0.1.1 24
[R1-LoopBack0]interface LoopBack 1
[R1-LoopBack1]ip address 10.2.0.1 24
[R1-LoopBack1]interface LoopBack 2
[R1-LoopBack2]ip address 10.2.1.1 24

<R2>system-view
Enter system view, return user view with Ctrl+Z.
[R2]interface GigabitEthernet 0/0/0
[R2-GigabitEthernet0/0/0]ip address 10.0.124.2 24
[R2-GigabitEthernet0/0/0]interface Serial 2/0/0
[R2-Serial2/0/0]ip address 10.0.23.2 24
[R2-Serial2/0/0]interface LoopBack 0
[R2-LoopBack0]ip address 10.0.2.2 24

<R3>system-view
Enter system view, return user view with Ctrl+Z.
[R3]interface Serial 2/0/0
[R3-Serial2/0/0]ip address 10.0.23.3 24
[R3-Serial2/0/0]interface Serial 3/0/0
[R3-Serial3/0/0]ip address 10.0.35.3 24
[R3-Serial3/0/0]interface LoopBack 0
[R3-LoopBack0]ip address 10.0.3.3 24

<R4>system-view
Enter system view, return user view with Ctrl+Z.
[R4]interface GigabitEthernet 0/0/0
[R4-GigabitEthernet0/0/0]ip address 10.0.124.4 24
[R4-GigabitEthernet0/0/0]interface LoopBack 0
[R4-LoopBack0]ip address 10.0.4.4 24

<R5>system-view
Enter system view, return user view with Ctrl+Z.
[R5]interface Serial 1/0/0
[R5-Serial1/0/0]ip address 10.0.35.5 24
[R5-Serial1/0/0]interface LoopBack 0
[R5-LoopBack0]ip address 10.0.5.5 24
[R5-LoopBack0]interface LoopBack 1
[R5-LoopBack1]ip address 10.1.0.1 24
[R5-LoopBack1]interface LoopBack 2
[R5-LoopBack2]ip address 10.1.1.1 24
```

配置完成后，测试直连链路的连通性。

```
[R2]ping -c 1 10.0.124.1
  PING 10.0.124.1: 56  data bytes, press CTRL_C to break
    Reply from 10.0.124.1: bytes=56 Sequence=1 ttl=255 time=5 ms

  --- 10.0.124.1 ping statistics ---
    1 packet(s) transmitted
    1 packet(s) received
    0.00% packet loss
    round-trip min/avg/max = 5/5/5 ms

[R2]ping -c 1 10.0.124.4
  PING 10.0.124.4: 56  data bytes, press CTRL_C to break
    Reply from 10.0.124.4: bytes=56 Sequence=1 ttl=255 time=14 ms

  --- 10.0.124.4 ping statistics ---
    1 packet(s) transmitted
    1 packet(s) received
    0.00% packet loss
    round-trip min/avg/max = 14/14/14 ms

[R2]ping -c 1 10.0.23.3
  PING 10.0.23.3: 56  data bytes, press CTRL_C to break
    Reply from 10.0.23.3: bytes=56 Sequence=1 ttl=255 time=41 ms

  --- 10.0.23.3 ping statistics ---
    1 packet(s) transmitted
    1 packet(s) received
    0.00% packet loss
    round-trip min/avg/max = 41/41/41 ms

[R3]ping -c 1 10.0.35.5
  PING 10.0.35.5: 56  data bytes, press CTRL_C to break
    Reply from 10.0.35.5: bytes=56 Sequence=1 ttl=255 time=38 ms

  --- 10.0.35.5 ping statistics ---
    1 packet(s) transmitted
    1 packet(s) received
    0.00% packet loss
    round-trip min/avg/max = 38/38/38 ms
```

步骤二. 配置多区域 OSPF

为保证OSPF的Router ID稳定，我们通常手工指定路由器的Router ID。有2种方法可以手工指定一台路由器运行OSPF的Router ID，第一种方式是在系统视图下使用**router id**的命令。

```
[R1]router id 10.0.1.1
```

第二种方式是在启动OSPF进程时加上参数**router-id**。

```
[R1]ospf 1 router-id 10.0.1.1
```

当路由器上同时配置了这两条命令以后，路由器最终会选取第二种方式配置的值作为Router ID。如果在一台路由器上需要起多个OSPF进程，且每个OSPF进程的Router ID需要不一样时，我们只能使用第二种方式来指定Router ID。

在R1上配置Loopback 0接口及GigabitEthernet 0/0/0属于区域2。这里我们将所有OSPF区域的Loopback接口，修改其OSPF网络类型为Broadcast类型，以便于OSPF发布Loopback口的真实掩码信息。

```
[R1]ospf 1 router-id 10.0.1.1
[R1-ospf-1]area 2
[R1-ospf-1-area-0.0.0.2]network 10.0.124.1 0.0.0.0
[R1-ospf-1-area-0.0.0.2]quit
[R1-ospf-1]quit
[R1]interface LoopBack 0
[R1-LoopBack0]ospf network-type broadcast
[R1-LoopBack0]quit
```

在R2上配置Loopback 0和Serial 2/0/0接口属于区域0，GigabitEthernet 0/0/0属于区域2。

```
[R2]ospf 1 router-id 10.0.2.2
[R2-ospf-1]area 0
[R2-ospf-1-area-0.0.0.0]network 10.0.23.2 0.0.0.0
[R2-ospf-1-area-0.0.0.0]network 10.0.2.2 0.0.0.0
[R2-ospf-1-area-0.0.0.0]quit
[R2-ospf-1]area 2
[R2-ospf-1-area-0.0.0.2]network 10.0.124.2 0.0.0.0
[R2-ospf-1-area-0.0.0.2]quit
[R2-ospf-1]quit
[R2]interface LoopBack 0
[R2-LoopBack0]ospf network-type broadcast
[R2-LoopBack0]quit
```

在R3上配置Loopback 0和Serial 2/0/0接口属于区域0，Serial 3/0/0属于区域1。

```
[R3]ospf 1 router-id 10.0.3.3
[R3-ospf-1]area 0
[R3-ospf-1-area-0.0.0.0]network 10.0.3.3 0.0.0.0
[R3-ospf-1-area-0.0.0.0]network 10.0.23.3 0.0.0.0
[R3-ospf-1-area-0.0.0.0]quit
[R3-ospf-1]area 1
[R3-ospf-1-area-0.0.0.1]network 10.0.35.3 0.0.0.0
[R3-ospf-1-area-0.0.0.1]quit
[R3-ospf-1]quit
[R3]interface LoopBack 0
[R3-LoopBack0]ospf network-type broadcast
[R3-LoopBack0]quit
```

在R4上配置Loopback 0及GigabitEthernet 0/0/0属于区域2。

```
[R4]ospf 1 router-id 10.0.4.4
[R4-ospf-1]area 2
[R4-ospf-1-area-0.0.0.2]network 10.0.4.4 0.0.0.0
[R4-ospf-1-area-0.0.0.2]network 10.0.124.4 0.0.0.0
[R4-ospf-1-area-0.0.0.2]quit
[R4-ospf-1]quit
[R4]interface LoopBack 0
[R4-LoopBack0]ospf network-type broadcast
[R4-LoopBack0]quit
```

在R5上配置所有的Loopback接口及Serial 1/0/0属于区域1。

```
[R5]ospf 1 router-id 10.0.5.5
[R5-ospf-1]area 1
[R5-ospf-1-area-0.0.0.1]network 10.0.5.5 0.0.0.0
[R5-ospf-1-area-0.0.0.1]network 10.1.0.1 0.0.0.0
[R5-ospf-1-area-0.0.0.1]network 10.1.1.1 0.0.0.0
[R5-ospf-1-area-0.0.0.1]network 10.0.35.5 0.0.0.0
[R5-ospf-1-area-0.0.0.1]quit
[R5-ospf-1]quit
[R5]interface LoopBack 0
[R5-LoopBack0]ospf network-type broadcast
[R5-LoopBack0]quit
[R5]interface LoopBack 1
[R5-LoopBack1]ospf network-type broadcast
[R5-LoopBack1]quit
[R5]interface LoopBack 2
```

```
[R5-LoopBack2]ospf network-type broadcast
[R5-LoopBack2]quit
```

配置完成后，在R1上查看路由表。

```
[R1]display ip routing-table
Route Flags: R - relay, D - download to fib
------------------------------------------------------------------------------
Routing Tables: Public
         Destinations : 24      Routes : 24

Destination/Mask    Proto  Pre  Cost    Flags NextHop        Interface

      10.0.1.0/24   Direct  0    0        D   10.0.1.1        LoopBack0
      10.0.1.1/32   Direct  0    0        D   127.0.0.1       InLoopBack0
    10.0.1.255/32   Direct  0    0        D   127.0.0.1       InLoopBack0
      10.0.2.0/24   OSPF    10   1        D   10.0.124.2    GigabitEthernet0/0/0
      10.0.3.0/24   OSPF    10   1563     D   10.0.124.2    GigabitEthernet0/0/0
      10.0.4.0/24   OSPF    10   1        D   10.0.124.4    GigabitEthernet0/0/0
      10.0.5.0/24   OSPF    10   3125     D   10.0.124.2    GigabitEthernet0/0/0
     10.0.23.0/24   OSPF    10   1563     D   10.0.124.2    GigabitEthernet0/0/0
     10.0.35.0/24   OSPF    10   3125     D   10.0.124.2    GigabitEthernet0/0/0
    10.0.124.0/24   Direct  0    0        D   10.0.124.1    GigabitEthernet0/0/0
    10.0.124.1/32   Direct  0    0        D   127.0.0.1       InLoopBack0
  10.0.124.255/32   Direct  0    0        D   127.0.0.1       InLoopBack0
      10.1.0.0/24   OSPF    10   3125     D   10.0.124.2    GigabitEthernet0/0/0
      10.1.1.0/24   OSPF    10   3125     D   10.0.124.2    GigabitEthernet0/0/0
    10.2.0.255/32   Direct  0    0        D   127.0.0.1       InLoopBack0
      10.2.1.0/24   Direct  0    0        D   10.2.1.1        LoopBack2
      10.2.1.1/32   Direct  0    0        D   127.0.0.1       InLoopBack0
    10.2.1.255/32   Direct  0    0        D   127.0.0.1       InLoopBack0
     127.0.0.0/8    Direct  0    0        D   127.0.0.1       InLoopBack0
     127.0.0.1/32   Direct  0    0        D   127.0.0.1       InLoopBack0
127.255.255.255/32  Direct  0    0        D   127.0.0.1       InLoopBack0
255.255.255.255/32  Direct  0    0        D   127.0.0.1       InLoopBack0
```

该路由器上已拥有全网所有的路由条目。

在R1上测试到其他路由器Loopback接口的连通性。

```
[R1]ping -c 1 10.0.2.2
  PING 10.0.2.2: 56  data bytes, press CTRL_C to break
    Reply from 10.0.2.2: bytes=56 Sequence=1 ttl=255 time=3 ms

  --- 10.0.2.2 ping statistics ---
```

```
    1 packet(s) transmitted
    1 packet(s) received
    0.00% packet loss
    round-trip min/avg/max = 3/3/3 ms

[R1]ping -c 1 10.0.5.5
  PING 10.0.5.5: 56  data bytes, press CTRL_C to break
    Reply from 10.0.5.5: bytes=56 Sequence=1 ttl=253 time=88 ms

  --- 10.0.5.5 ping statistics ---
    1 packet(s) transmitted
    1 packet(s) received
    0.00% packet loss
    round-trip min/avg/max = 88/88/88 ms

[R1]ping -c 1 10.0.4.4
  PING 10.0.4.4: 56  data bytes, press CTRL_C to break
    Reply from 10.0.4.4: bytes=56 Sequence=1 ttl=255 time=3 ms

  --- 10.0.4.4 ping statistics ---
    1 packet(s) transmitted
    1 packet(s) received
    0.00% packet loss
    round-trip min/avg/max = 3/3/3 ms
```

我们使用**display ospf brief**命令在R2上查看路由器运行的基本OSPF信息。

```
[R2]display ospf brief

         OSPF Process 1 with Router ID 10.0.2.2
                 OSPF Protocol Information

 RouterID: 10.0.2.2         Border Router:  AREA
 Multi-VPN-Instance is not enabled
 Global DS-TE Mode: Non-Standard IETF Mode
 Graceful-restart capability: disabled
 Helper support capability  : not configured
 Spf-schedule-interval: max 10000ms, start 500ms, hold 1000ms
 Default ASE parameters: Metric: 1 Tag: 1 Type: 2
 Route Preference: 10
 ASE Route Preference: 150
 SPF Computation Count: 19
 RFC 1583 Compatible
 Retransmission limitation is disabled
```

```
Area Count: 2   Nssa Area Count: 0
ExChange/Loading Neighbors: 0

Area: 0.0.0.0
Authtype: None   Area flag: Normal
SPF scheduled Count: 19
ExChange/Loading Neighbors: 0

Interface: 10.0.2.2 (LoopBack0)
Cost: 0      State: DR       Type: Broadcast    MTU: 1500
Priority: 1
Designated Router: 10.0.2.2
Backup Designated Router: 0.0.0.0
Timers: Hello 10 , Dead 40 , Poll  120 , Retransmit 5 , Transmit Delay 1

Interface: 10.0.23.2 (Serial2/0/0) --> 10.0.23.3
Cost: 1562    State: P-2-P     Type: P2P      MTU: 1500
Timers: Hello 10 , Dead 40 , Poll  120 , Retransmit 5 , Transmit Delay 1

Area: 0.0.0.2
Authtype: None   Area flag: Normal
SPF scheduled Count: 17
ExChange/Loading Neighbors: 0

Interface: 10.0.124.2 (GigabitEthernet0/0/0)
Cost: 1      State: BDR      Type: Broadcast    MTU: 1500
Priority: 1
Designated Router: 10.0.124.1
Backup Designated Router: 10.0.124.2
Timers: Hello 10 , Dead 40 , Poll  120 , Retransmit 5 , Transmit Delay 1
```

第一行Border Router: AREA 表示该路由器是一台ABR；如果路由器是一台区域内路由器，该值为空；如果路由器是一台ASBR，该值为 AS。

该路由器共有三个接口参加OSPF运算，我们已手工将Loopback 0接口的网络类型修改为Broadcast。Serial2/0/0的封装类型为PPP，所以默认的网络类型为点对点。另外GigabitEthernet 0/0/0连接到区域2，是广播型网络。

我们在R2上使用**display ospf peer brief**命令查看路由器的OSPF邻居关系建立情况。可以看到，在区域0，R2有一个邻居10.0.3.3，在区域2，R2有2个邻居：10.0.1.1和10.0.4.4，R2与他们都形成了邻接关系（Full）。

```
[R2]display ospf peer brief

      OSPF Process 1 with Router ID 10.0.2.2
```

```
              Peer Statistic Information
----------------------------------------------------------------------------
Area Id          Interface                     Neighbor id      State
0.0.0.0          Serial2/0/0                    10.0.3.3         Full
0.0.0.2          GigabitEthernet0/0/0           10.0.1.1         Full
0.0.0.2          GigabitEthernet0/0/0           10.0.4.4         Full
----------------------------------------------------------------------------
```

我们在R2上使用**display ospf lsdb**命令查看路由器的OSPF数据库信息。我们可以发现由于R2是一台ABR，所以在该路由器上维护了2个LSDB，分别用来描述区域0和区域2的路由。

```
[R2]display ospf lsdb

       OSPF Process 1 with Router ID 10.0.2.2
              Link State Database

                    Area: 0.0.0.0
Type      LinkState ID    AdvRouter          Age  Len   Sequence   Metric
Router      10.0.3.3        10.0.3.3          788  60    80000008       0
Router      10.0.2.2        10.0.2.2          869  60    80000008       0
Sum-Net     10.0.35.0       10.0.3.3          846  28    80000002    1562
Sum-Net     10.0.124.0      10.0.2.2         1259  28    80000002       1
Sum-Net     10.1.1.0        10.0.3.3         1565  28    80000001    1562
Sum-Net     10.0.5.0        10.0.3.3         1594  28    80000001    1562
Sum-Net     10.1.0.0        10.0.3.3         1584  28    80000001    1562
Sum-Net     10.0.4.0        10.0.2.2          538  28    80000002       1

                    Area: 0.0.0.2
Type      LinkState ID    AdvRouter          Age  Len   Sequence   Metric
Router      10.0.4.4        10.0.4.4          504  48    80000008       1
Router      10.0.2.2        10.0.2.2          558  36    80000006       1
Router      10.0.1.1        10.0.1.1          568  60    80000011       1
Network     10.0.124.1      10.0.1.1          559  36    80000005       0
Sum-Net     10.0.35.0       10.0.2.2          846  28    80000002    3124
Sum-Net     10.0.3.0        10.0.2.2          830  28    80000002    1562
Sum-Net     10.0.2.0        10.0.2.2         1249  28    80000002       0
Sum-Net     10.1.1.0        10.0.2.2         1565  28    80000001    3124
Sum-Net     10.0.5.0        10.0.2.2         1595  28    80000001    3124
Sum-Net     10.1.0.0        10.0.2.2         1584  28    80000001    3124
Sum-Net     10.0.23.0       10.0.2.2         1261  28    80000002    1562
```

步骤三. 配置 OSPF 区域之间的路由汇总

首先查看R2和R3的OSPF路由表。

```
[R2]display ip routing-table protocol ospf
Route Flags: R - relay, D - download to fib
------------------------------------------------------------------------------
Public routing table : OSPF
        Destinations : 8       Routes : 8

OSPF routing table status : <Active>
        Destinations : 8       Routes : 8

Destination/Mask    Proto  Pre  Cost   Flags NextHop        Interface


      10.0.3.0/24  OSPF    10   1562     D   10.0.23.3      Serial2/0/0
      10.0.4.0/24  OSPF    10   1        D   10.0.124.4   GigabitEthernet0/0/0
      10.0.5.0/24  OSPF    10   3124     D   10.0.23.3      Serial2/0/0
     10.0.35.0/24  OSPF    10   3124     D   10.0.23.3      Serial2/0/0
      10.1.0.0/24  OSPF    10   3124     D   10.0.23.3      Serial2/0/0
      10.1.1.0/24  OSPF    10   3124     D   10.0.23.3      Serial2/0/0

OSPF routing table status : <Inactive>
        Destinations : 0       Routes : 0

[R3]display ip routing-table protocol ospf
Route Flags: R - relay, D - download to fib
------------------------------------------------------------------------------
Public routing table : OSPF
        Destinations : 8       Routes : 8

OSPF routing table status : <Active>
        Destinations : 8       Routes : 8

Destination/Mask   Proto  Pre  Cost     Flags NextHop        Interface


      10.0.2.0/24   OSPF   10   1562       D   10.0.23.2      Serial2/0/0
      10.0.4.0/24   OSPF   10   1563       D   10.0.23.2      Serial2/0/0
      10.0.5.0/24   OSPF   10   1562       D   10.0.35.5      Serial3/0/0
    10.0.124.0/24   OSPF   10   1563       D   10.0.23.2      Serial2/0/0
      10.1.0.0/24   OSPF   10   1562       D   10.0.35.5      Serial3/0/0
      10.1.1.0/24   OSPF   10   1562       D   10.0.35.5      Serial3/0/0
```

```
OSPF routing table status : <Inactive>
       Destinations : 0      Routes : 0
```

10.1.0.0/24和10.1.1.0/24两条路由信息均以详细条目出现。

对于这样的路由信息，可以进行汇总，再向其他区域发送。一方面减少其他区域的路由表条目，另外一方面还可以减少路由振荡情况的发生。我们可在R3上使用**abr-summary**的命令将R5的Loopback1和Loopback2接口的网段进行汇总发送。

```
[R3]ospf 1
[R3-ospf-1]area 1
[R3-ospf-1-area-0.0.0.1]abr-summary 10.1.0.0 255.255.254.0
```

配置完成后在R3和R2上分别查看汇总路由信息。

```
[R3]display ip routing-table protocol ospf
Route Flags: R - relay, D - download to fib
----------------------------------------------------------------------------
Public routing table : OSPF
       Destinations : 8      Routes : 8

OSPF routing table status : <Active>
       Destinations : 8      Routes : 8

Destination/Mask    Proto   Pre  Cost     Flags NextHop        Interface

      10.0.2.0/24   OSPF    10   1562       D   10.0.23.2      Serial2/0/0
      10.0.4.0/24   OSPF    10   1563       D   10.0.23.2      Serial2/0/0
      10.0.5.0/24   OSPF    10   1562       D   10.0.35.5      Serial3/0/0
    10.0.124.0/24   OSPF    10   1563       D   10.0.23.2      Serial2/0/0
      10.1.0.0/24   OSPF    10   1562       D   10.0.35.5      Serial3/0/0
      10.1.1.0/24   OSPF    10   1562       D   10.0.35.5      Serial3/0/0

OSPF routing table status : <Inactive>
       Destinations : 0      Routes : 0

[R2]display ip routing-table protocol ospf
Route Flags: R - relay, D - download to fib
----------------------------------------------------------------------------
Public routing table : OSPF
       Destinations : 7      Routes : 7

OSPF routing table status : <Active>
       Destinations : 7      Routes : 7
```

```
Destination/Mask    Proto   Pre  Cost     Flags NextHop       Interface

      10.0.3.0/24  OSPF    10   1562     D   10.0.23.3      Serial2/0/0
      10.0.4.0/24  OSPF    10   1        D   10.0.124.4   GigabitEthernet0/0/0
      10.0.5.0/24  OSPF    10   3124     D   10.0.23.3      Serial2/0/0
     10.0.35.0/24  OSPF    10   3124     D   10.0.23.3      Serial2/0/0
      10.1.0.0/23  OSPF    10   3124     D   10.0.23.3      Serial2/0/0

OSPF routing table status : <Inactive>
        Destinations : 0       Routes : 0
```

通过输出可以看到，在R3的路由表中，这2条路由仍以明细路由的形式出现，在R2上，仅存在汇总路由10.1.0.0/23。

配置完成后，测试其他路由器与网络10.1.0.0/24与10.1.1.0/24的连通性。

```
[R1]ping -c 1 10.1.0.1
  PING 10.1.0.1: 56  data bytes, press CTRL_C to break
    Reply from 10.1.0.1: bytes=56 Sequence=1 ttl=253 time=66 ms

  --- 10.1.0.1 ping statistics ---
    1 packet(s) transmitted
    1 packet(s) received
    0.00% packet loss
    round-trip min/avg/max = 66/66/66 ms

[R1]ping -c 1 10.1.1.1
  PING 10.1.1.1: 56  data bytes, press CTRL_C to break
    Reply from 10.1.1.1: bytes=56 Sequence=1 ttl=253 time=66 ms

  --- 10.1.1.1 ping statistics ---
    1 packet(s) transmitted
    1 packet(s) received
    0.00% packet loss
    round-trip min/avg/max = 66/66/66 ms

[R2]ping -c 1 10.1.0.1
  PING 10.1.0.1: 56  data bytes, press CTRL_C to break
    Reply from 10.1.0.1: bytes=56 Sequence=1 ttl=254 time=69 ms

  --- 10.1.0.1 ping statistics ---
    1 packet(s) transmitted
    1 packet(s) received
```

```
    0.00% packet loss
    round-trip min/avg/max = 69/69/69 ms

[R3]ping -c 1 10.1.0.1
  PING 10.1.0.1: 56  data bytes, press CTRL_C to break
    Reply from 10.1.0.1: bytes=56 Sequence=1 ttl=255 time=29 ms

  --- 10.1.0.1 ping statistics ---
    1 packet(s) transmitted
    1 packet(s) received
    0.00% packet loss
    round-trip min/avg/max = 29/29/29 ms
```

步骤四. 修改 OSPF 的参考带宽值

在实际网络我们可能使用了千兆甚至万兆以太网。但是由于OSPF的默认参考带宽值为100Mbps，并且接口代价值仅为整数，所以OSPF无法在带宽上区分百兆以太网和千兆以太网。

在R2上修改OSPF的参考带宽值为10Gbps。这里，使用命令**bandwidth-reference**进行修改，相应带宽参数值的单位为Mbps。

```
[R2-ospf-1]bandwidth-reference 10000
```

在R2上查看OSPF邻居关系，以及路由信息学习情况，我们可以看到，在路由表中，Cost值已经发生了变化。

```
[R2]display ip routing-table protocol ospf
Route Flags: R - relay, D - download to fib
------------------------------------------------------------------------------
Public routing table : OSPF
         Destinations : 7        Routes : 7

OSPF routing table status : <Active>
         Destinations : 7        Routes : 7

Destination/Mask   Proto   Pre  Cost    Flags NextHop        Interface

      10.0.3.0/24  OSPF    10   65535     D   10.0.23.3       Serial2/0/0
      10.0.4.0/24  OSPF    10   10        D   10.0.124.4    GigabitEthernet0/0/0
      10.0.5.0/24  OSPF    10   67097     D   10.0.23.3       Serial2/0/0
     10.0.35.0/24  OSPF    10   67097     D   10.0.23.3       Serial2/0/0
      10.1.0.0/23  OSPF    10   67097     D   10.0.23.3       Serial2/0/0
```

```
OSPF routing table status : <Inactive>
        Destinations : 0        Routes : 0
```

在运行OSPF的多个区域内，OSPF的参考带宽值必须一致，否则OSPF无法正常工作。修改所有路由器的OSPF参考带宽值为10Gbps。

```
[R1-ospf-1]bandwidth-reference 10000

[R3-ospf-1]bandwidth-reference 10000

[R4-ospf-1]bandwidth-reference 10000

[R5-ospf-1]bandwidth-reference 10000
```

在R2上查看邻居列表、路由表 ,观察OSPF邻居关系以及路由信息是否正常。

```
[R2]display ospf peer brief

        OSPF Process 1 with Router ID 10.0.2.2
                Peer Statistic Information
 ----------------------------------------------------------------------------
 Area Id         Interface                     Neighbor id      State
 0.0.0.0         Serial2/0/0                    10.0.3.3         Full
 0.0.0.2         GigabitEthernet0/0/0           10.0.1.1         Full
 0.0.0.2         GigabitEthernet0/0/0           10.0.4.4         Full
 ----------------------------------------------------------------------------

[R2]display ip routing-table protocol ospf
Route Flags: R - relay, D - download to fib
------------------------------------------------------------------------------
Public routing table : OSPF
        Destinations : 7        Routes : 7

OSPF routing table status : <Active>
        Destinations : 7        Routes : 7

Destination/Mask   Proto   Pre  Cost   Flags NextHop        Interface

      10.0.3.0/24  OSPF    10   65535    D   10.0.23.3      Serial2/0/0
      10.0.4.0/24  OSPF    10   10       D   10.0.124.4   GigabitEthernet0/0/0
      10.0.5.0/24  OSPF    10   131070   D   10.0.23.3      Serial2/0/0
     10.0.35.0/24  OSPF    10   131070   D   10.0.23.3      Serial2/0/0
      10.1.0.0/23  OSPF    10   131070   D   10.0.23.3      Serial2/0/0
```

```
OSPF routing table status : <Inactive>
       Destinations : 0       Routes : 0
```

如上所示，路由信息正常。另外可测试网络的连通性。

步骤五. 配置将直连路由汇总并引入到 OSPF 区域

R1的Loopback1和Loopback2接口不属于OSPF区域。将这两条直连路由引入到OSPF区域，并在R1上执行路由汇总。

```
[R1]ospf
[R1-ospf-1]import-route direct
[R1-ospf-1]asbr-summary 10.2.0.0 255.255.254.0
```

在R1上查看外部路由信息。

```
[R1]display ospf lsdb ase 10.2.0.0

       OSPF Process 1 with Router ID 10.0.1.1
              Link State Database


  Type      : External
  Ls id     : 10.2.0.0
  Adv rtr   : 10.0.1.1
  Ls age    : 293
  Len       : 36
  Options   :  E
  seq#      : 80000001
  chksum    : 0x2b6
  Net mask  : 255.255.254.0
  TOS 0  Metric: 2
  E type    : 2
  Forwarding Address : 0.0.0.0
  Tag       : 1
  Priority  : Low
```

R1通过一条第五类LSA向其他路由器通告了网段10.2.0.0，子网掩码是255.255.254.0。

在其他路由器上查看汇总路由，并测试网络连通性。

```
[R2]display ip routing-table protocol ospf
```

```
Route Flags: R - relay, D - download to fib
------------------------------------------------------------------------------
Public routing table : OSPF
        Destinations : 7       Routes : 7

OSPF routing table status : <Active>
        Destinations : 7       Routes : 7

Destination/Mask    Proto   Pre  Cost     Flags NextHop       Interface

      10.0.1.0/24  O_ASE   150  1        D   10.0.124.1   GigabitEthernet0/0/0
      10.0.3.0/24  OSPF    10   65535    D   10.0.23.3     Serial2/0/0
      10.0.4.0/24  OSPF    10   10       D   10.0.124.4   GigabitEthernet0/0/0
      10.0.5.0/24  OSPF    10   131070   D   10.0.23.3     Serial2/0/0
     10.0.35.0/24  OSPF    10   131070   D   10.0.23.3     Serial2/0/0
      10.1.0.0/23  OSPF    10   131070   D   10.0.23.3     Serial2/0/0
      10.2.0.0/23  O_ASE   150  2        D   10.0.124.1   GigabitEthernet0/0/0

OSPF routing table status : <Inactive>
        Destinations : 0       Routes : 0

[R2]ping -c 1 10.2.0.1
  PING 10.2.0.1: 56  data bytes, press CTRL_C to break
    Reply from 10.2.0.1: bytes=56 Sequence=1 ttl=255 time=2 ms

  --- 10.2.0.1 ping statistics ---
    1 packet(s) transmitted
    1 packet(s) received
    0.00% packet loss
    round-trip min/avg/max = 2/2/2 ms

[R2]ping -c 1 10.2.1.1
  PING 10.2.1.1: 56  data bytes, press CTRL_C to break
    Reply from 10.2.1.1: bytes=56 Sequence=1 ttl=255 time=2 ms

  --- 10.2.1.1 ping statistics ---
    1 packet(s) transmitted
    1 packet(s) received
    0.00% packet loss
    round-trip min/avg/max = 2/2/2 ms
```

在R2上可以看到一条掩码为23位的汇总路由。

将R1的Loopback 2接口删除，查看R2上路由条目变化情况。我们可以看到，

当Loopback 2接口不存在了，汇总路由仍然存在。

```
[R1]undo interface LoopBack 2

[R2]display ip routing-table protocol ospf
Route Flags: R - relay, D - download to fib
------------------------------------------------------------------------------
Public routing table : OSPF
        Destinations : 7       Routes : 7

OSPF routing table status : <Active>
        Destinations : 7       Routes : 7

Destination/Mask   Proto   Pre  Cost    Flags NextHop        Interface

      10.0.1.0/24  O_ASE   150  1        D   10.0.124.1   GigabitEthernet0/0/0
      10.0.3.0/24  OSPF    10   65535    D   10.0.23.3     Serial2/0/0
      10.0.4.0/24  OSPF    10   10       D   10.0.124.4   GigabitEthernet0/0/0
      10.0.5.0/24  OSPF    10   131070   D   10.0.23.3     Serial2/0/0
     10.0.35.0/24  OSPF    10   131070   D   10.0.23.3     Serial2/0/0
      10.1.0.0/23  OSPF    10   131070   D   10.0.23.3     Serial2/0/0
      10.2.0.0/23  O_ASE   150  2        D   10.0.124.1   GigabitEthernet0/0/0

OSPF routing table status : <Inactive>
        Destinations : 0       Routes : 0
```

在R5设备上向10.2.1.1地址发送Tracert数据包。

```
<R5>tracert 10.2.1.1
 traceroute to  10.2.1.1(10.2.1.1), max hops: 30 ,packet length: 40,press CTRL_C
to break
 1 10.0.35.3 62 ms  28 ms  27 ms
 2 10.0.23.2 54 ms  58 ms  57 ms
 3  *  *  *
...
```

我们可以看到虽然Loopback 2接口被删除了，到达该目的地址的数据包仍然被R2和R3转发，直到R1上该数据包被丢弃。

步骤六.　OSPF 引入缺省路由

R4的Loopback0接口连接到Internet。在R4上配置缺省路由，下一跳指向Loopback0。

```
[R4]ip route-static 0.0.0.0 0.0.0.0 LoopBack 0
```

将这条缺省路由引入到OSPF区域，定义类型为1，Cost值为10，并且定义为永久引入。

```
[R4]ospf 1
[R4-ospf-1]default-route-advertise always type 1
```

在R2上查看缺省路由的学习情况。我们可以看到R2通过第五类LSA学习到了一条默认路由，下一跳是R4的接口地址。

```
[R2]dis ip routing-table protocol ospf
Route Flags: R - relay, D - download to fib
------------------------------------------------------------------------------
Public routing table : OSPF
        Destinations : 8        Routes : 8

OSPF routing table status : <Active>
        Destinations : 8        Routes : 8

Destination/Mask   Proto   Pre  Cost    Flags NextHop        Interface

       0.0.0.0/0   O_ASE   150  11        D   10.0.124.4    GigabitEthernet0/0/0
      10.0.1.0/24  O_ASE   150  1         D   10.0.124.1    GigabitEthernet0/0/0
      10.0.3.0/24  OSPF    10   65535     D   10.0.23.3       Serial2/0/0
      10.0.4.0/24  OSPF    10   10        D   10.0.124.4    GigabitEthernet0/0/0
      10.0.5.0/24  OSPF    10   131070    D   10.0.23.3       Serial2/0/0
     10.0.35.0/24  OSPF    10   131070    D   10.0.23.3       Serial2/0/0
      10.1.0.0/23  OSPF    10   131070    D   10.0.23.3       Serial2/0/0
      10.2.0.0/23  O_ASE   150  2         D   10.0.124.1    GigabitEthernet0/0/0

OSPF routing table status : <Inactive>
        Destinations : 0        Routes : 0
```

最后测试R5路由器与10.0.4.4之间的连通性。

```
[R5]ping -c 1 10.0.4.4
  PING 10.0.4.4: 56  data bytes, press CTRL_C to break
    Reply from 10.0.4.4: bytes=56 Sequence=1 ttl=253 time=78 ms

  --- 10.0.4.4 ping statistics ---
    1 packet(s) transmitted
    1 packet(s) received
    0.00% packet loss
    round-trip min/avg/max = 78/78/78 ms
```

步骤七. 修改 OSPF 中两类路由的优先级

查看R1的路由表，关注OSPF不同类型路由的优先级信息。

```
[R1]dis ip routing-table protocol ospf
Route Flags: R - relay, D - download to fib
------------------------------------------------------------------------------
Public routing table : OSPF
        Destinations : 8       Routes : 8

OSPF routing table status : <Active>
        Destinations : 8       Routes : 8

Destination/Mask    Proto  Pre  Cost     Flags NextHop        Interface

       0.0.0.0/0   O_ASE  150  11        D   10.0.124.4    GigabitEthernet0/0/0
      10.0.2.0/24  OSPF   10   10        D   10.0.124.2    GigabitEthernet0/0/0
      10.0.3.0/24  OSPF   10   65545     D   10.0.124.2    GigabitEthernet0/0/0
      10.0.4.0/24  OSPF   10   10        D   10.0.124.4    GigabitEthernet0/0/0
      10.0.5.0/24  OSPF   10   131080    D   10.0.124.2    GigabitEthernet0/0/0
     10.0.23.0/24  OSPF   10   65545     D   10.0.124.2    GigabitEthernet0/0/0
     10.0.35.0/24  OSPF   10   131080    D   10.0.124.2    GigabitEthernet0/0/0
      10.1.0.0/23  OSPF   10   131080    D   10.0.124.2    GigabitEthernet0/0/0

OSPF routing table status : <Inactive>
        Destinations : 0       Routes : 0
```

默认情况下，OSPF区域内和区域之间的路由，优先级为10。OSPF外部路由，优先级为150。

修改R1和R4路由器上的OSPF区域内和区域之间的路由优先级为20，修改OSPF外部路由的优先级为50。

```
[R1]ospf
[R1-ospf-1]preference 20
[R1-ospf-1]preference ase 50

[R4]ospf
[R4-ospf-1]preference 20
[R4-ospf-1]preference ase 50
```

查看路由表中OSPF内部路由及外部路由的优先级，确认已修改成功。

```
[R1]dis ip routing-table protocol ospf
Route Flags: R - relay, D - download to fib
------------------------------------------------------------------------------
Public routing table : OSPF
        Destinations : 8       Routes : 8

OSPF routing table status : <Active>
        Destinations : 8       Routes : 8

Destination/Mask   Proto   Pre  Cost    Flags NextHop        Interface

       0.0.0.0/0   O_ASE   50   11        D   10.0.124.4    GigabitEthernet0/0/0
      10.0.2.0/24  OSPF    20   10        D   10.0.124.2    GigabitEthernet0/0/0
      10.0.3.0/24  OSPF    20   65545     D   10.0.124.2    GigabitEthernet0/0/0
      10.0.4.0/24  OSPF    20   10        D   10.0.124.4    GigabitEthernet0/0/0
      10.0.5.0/24  OSPF    20   131080    D   10.0.124.2    GigabitEthernet0/0/0
     10.0.23.0/24  OSPF    20   65545     D   10.0.124.2    GigabitEthernet0/0/0
     10.0.35.0/24  OSPF    20   131080    D   10.0.124.2    GigabitEthernet0/0/0
      10.1.0.0/23  OSPF    20   131080    D   10.0.124.2    GigabitEthernet0/0/0

OSPF routing table status : <Inactive>
        Destinations : 0       Routes : 0
```

路由优先级仅在本地有效，用于衡量在本地通过多种方式学到的路由的优略程度。本地区域的不同路由器，如果优先级信息不同，也可以正常工作。

附加实验：思考并验证

思考在步骤六中，定义缺省路由的永久发布的作用是什么？有哪些优点和缺点？

路由汇总就像一把双刃剑，有好处也有坏处。思考并总结使用路由汇总的好处和坏处，并分析如何避免这些坏处。

最终设备配置

```
<R1>display current-configuration
[V200R001C00SPC200]
#
 sysname R1
#
interface GigabitEthernet0/0/0
 ip address 10.0.124.1 255.255.255.0
```

```
#
interface LoopBack0
 ip address 10.0.1.1 255.255.255.0
 ospf network-type broadcast
#
interface LoopBack1
 ip address 10.2.0.1 255.255.255.0
#
ospf 1 router-id 10.0.1.1
 asbr-summary 10.2.0.0 255.255.254.0
 import-route direct
 preference 20
 preference ase 50
 bandwidth-reference 10000
 area 0.0.0.2
  network 10.0.124.1 0.0.0.0
#
return
```

```
<R2>display current-configuration
[V200R001C00SPC200]
#
 sysname R2
#
interface Serial2/0/0
 link-protocol ppp
 ip address 10.0.23.2 255.255.255.0
#
interface GigabitEthernet0/0/0
 ip address 10.0.124.2 255.255.255.0
#
interface LoopBack0
 ip address 10.0.2.2 255.255.255.0
 ospf network-type broadcast
#
ospf 1 router-id 10.0.2.2
 bandwidth-reference 10000
 area 0.0.0.0
  network 10.0.23.2 0.0.0.0
  network 10.0.2.2 0.0.0.0
 area 0.0.0.2
  network 10.0.124.2 0.0.0.0
#
```

```
return

<R3>display current-configuration
[V200R001C00SPC200]
#
 sysname R3
#
interface Serial2/0/0
 link-protocol ppp
 ip address 10.0.23.3 255.255.255.0
#
interface Serial3/0/0
 link-protocol ppp
 ip address 10.0.35.3 255.255.255.0
#
interface LoopBack0
 ip address 10.0.3.3 255.255.255.0
 ospf network-type broadcast
#
ospf 1 router-id 10.0.3.3
 bandwidth-reference 10000
 area 0.0.0.0
  network 10.0.3.3 0.0.0.0
  network 10.0.23.3 0.0.0.0
 area 0.0.0.1
  abr-summary 10.1.0.0 255.255.254.0
  network 10.0.35.3 0.0.0.0
#
return

<R4>display current-configuration
[V200R001C00SPC200]
#
 sysname R4
#
interface GigabitEthernet0/0/0
 ip address 10.0.124.4 255.255.255.0
#
interface LoopBack0
 ip address 10.0.4.4 255.255.255.0
 ospf network-type broadcast
#
ospf 1 router-id 10.0.4.4
```

```
 default-route-advertise always type 1
 preference 20
 preference ase 50
 bandwidth-reference 10000
 area 0.0.0.2
  network 10.0.4.4 0.0.0.0
  network 10.0.124.4 0.0.0.0
#
 ip route-static 0.0.0.0 0.0.0.0 LoopBack0
#
return

<R5>display current-configuration
[V200R001C00SPC200]
#
 sysname R5
#
interface Serial1/0/0
 link-protocol ppp
 ip address 10.0.35.5 255.255.255.0
#
interface LoopBack0
 ip address 10.0.5.5 255.255.255.0
 ospf network-type broadcast
#
interface LoopBack1
 ip address 10.1.0.1 255.255.255.0
 ospf network-type broadcast
#
interface LoopBack2
 ip address 10.1.1.1 255.255.255.0
 ospf network-type broadcast
#
ospf 1 router-id 10.0.5.5
 bandwidth-reference 10000
 area 0.0.0.1
  network 10.0.5.5 0.0.0.0
  network 10.1.0.1 0.0.0.0
  network 10.1.1.1 0.0.0.0
  network 10.0.35.5 0.0.0.0
#
return
```

实验 2-3 OSPF 的邻接关系和 LSA

学习目的

- 了解四个OSPF邻居路由器在以太网上邻居关系建立的过程
- 掌握对OSPF的DR的选举进行干预的方法
- 观察5种类型的LSA的内容，以及它们的作用
- 了解OSPF的LSR、LSU、LSAck数据包的相互发送情况

拓扑图

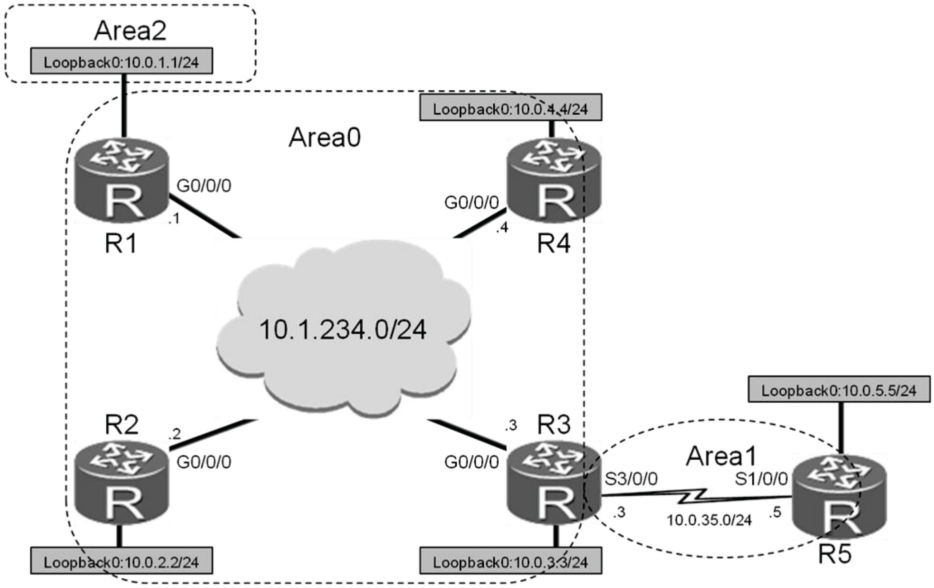


图2-3 OSPF的邻接关系和LSA

场景

你是公司的网络管理员。现在公司的网络中有五台AR G3路由器，其中R1、R2、R3和R4在公司总部，通过以太网互联。R5在公司分部，R3通过专线与公司总部的R3相连。由于网络规模较大，为了控制LSA的洪泛，你设计了多区域的OSPF互联方式。

其中R1的Loopback0接口属于区域2。R2、R3、R4的Loopback0接口与10.1.234.0/24网段属于区域0。R3与R5之间互联的网段属于区域1。R5的Loopback0接口属于OSPF外部网络。

同时为了明确设备的Router ID，你配置设备使用固定的地址作为Router ID。

在R1、R2、R3与R4之间互联的一台网络上，需要干预DR与BDR的选举。实际使用中将R3定义为DR、R2定义为BDR。R4设备定义为DROther。

学习任务

步骤一. 基础配置与 IP 编址

给所有路由器配置IP地址和掩码。配置时注意所有的Loopback接口配置掩码均为24位，模拟成一个单独的网段。

```
<R1>system-view
Enter system view, return user view with Ctrl+Z.
[R1]interface GigabitEthernet 0/0/0
[R1-GigabitEthernet0/0/0]ip address 10.1.234.1 24
[R1-GigabitEthernet0/0/0]interface LoopBack 0
[R1-LoopBack0]ip address 10.0.1.1 24

<R2>system-view
Enter system view, return user view with Ctrl+Z.
[R2]interface GigabitEthernet 0/0/0
[R2-GigabitEthernet0/0/0]ip address 10.1.234.2 24
[R2-GigabitEthernet0/0/0]interface LoopBack 0
[R2-LoopBack0]ip address 10.0.2.2 24

<R3>system-view
Enter system view, return user view with Ctrl+Z.
[R3]interface GigabitEthernet 0/0/0
[R3-GigabitEthernet0/0/0]ip address 10.1.234.3 24
[R3-GigabitEthernet0/0/0]interface Serial 3/0/0
[R3-Serial3/0/0]ip address 10.0.35.3 24
[R3-Serial3/0/0]interface LoopBack 0
[R3-LoopBack0]ip address 10.0.3.3 24

<R4>system-view
Enter system view, return user view with Ctrl+Z.
[R4]interface GigabitEthernet 0/0/0
[R4-GigabitEthernet0/0/0]ip address 10.1.234.4 24
```

```
[R4-GigabitEthernet0/0/0]interface LoopBack 0
[R4-LoopBack0]ip address 10.0.4.4 24

<R5>system-view
Enter system view, return user view with Ctrl+Z.
[R5]interface Serial 1/0/0
[R5-Serial1/0/0]ip address 10.0.35.5 24
[R5-Serial1/0/0]interface LoopBack 0
[R5-LoopBack0]ip address 10.0.5.5 24
```

配置完成后，测试直连链路的连通性。

```
[R1]ping -c 1 10.1.234.2
  PING 10.1.234.2: 56  data bytes, press CTRL_C to break
    Reply from 10.1.234.2: bytes=56 Sequence=1 ttl=255 time=13 ms

  --- 10.1.234.2 ping statistics ---
    1 packet(s) transmitted
    1 packet(s) received
    0.00% packet loss
    round-trip min/avg/max = 13/13/13 ms

[R1]ping -c 1 10.1.234.4
  PING 10.1.234.4: 56  data bytes, press CTRL_C to break
    Reply from 10.1.234.4: bytes=56 Sequence=1 ttl=255 time=6 ms

  --- 10.1.234.4 ping statistics ---
    1 packet(s) transmitted
    1 packet(s) received
    0.00% packet loss
    round-trip min/avg/max = 6/6/6 ms

[R3]ping -c 1 10.1.234.1
  PING 10.1.234.1: 56  data bytes, press CTRL_C to break
    Reply from 10.1.234.1: bytes=56 Sequence=1 ttl=255 time=13 ms

  --- 10.1.234.1 ping statistics ---
    1 packet(s) transmitted
    1 packet(s) received
    0.00% packet loss
    round-trip min/avg/max = 13/13/13 ms

[R3]ping -c 1 10.0.35.5
  PING 10.0.35.5: 56  data bytes, press CTRL_C to break
```

```
  Reply from 10.0.35.5: bytes=56 Sequence=1 ttl=255 time=32 ms

 --- 10.0.35.5 ping statistics ---
  1 packet(s) transmitted
  1 packet(s) received
  0.00% packet loss
  round-trip min/avg/max = 32/32/32 ms
```

步骤二. 配置多区域 OSPF

在R1上配置GigabitEthernet 0/0/0属于区域0，Loopback 0属于区域2。对所有OSPF区域的Loopback接口，修改其OSPF网络类型为Broadcast类型，以便于OSPF发布Loopback口的真实掩码信息。

```
[R1]ospf 1 router-id 10.0.1.1
[R1-ospf-1]area 0
[R1-ospf-1-area-0.0.0.0]network 10.1.234.1 0.0.0.0
[R1-ospf-1-area-0.0.0.0]area 2
[R1-ospf-1-area-0.0.0.2]network 10.0.1.1 0.0.0.0
[R1-ospf-1-area-0.0.0.2]interface LoopBack 0
[R1-LoopBack0]ospf network-type broadcast
```

R2、R4的所有接口均位于区域0中。

```
[R2]ospf 1 router-id 10.0.2.2
[R2-ospf-1]area 0
[R2-ospf-1-area-0.0.0.0]network 10.1.234.2 0.0.0.0
[R2-ospf-1-area-0.0.0.0]network 10.0.2.2 0.0.0.0
[R2-ospf-1-area-0.0.0.0]interface LoopBack 0
[R2-LoopBack0]ospf network-type broadcast

[R4]ospf 1 router-id 10.0.4.4
[R4-ospf-1]area 0
[R4-ospf-1-area-0.0.0.0]network 10.1.234.4 0.0.0.0
[R4-ospf-1-area-0.0.0.0]network 10.0.4.4 0.0.0.0
[R4-ospf-1-area-0.0.0.0]interface LoopBack 0
[R4-LoopBack0]ospf network-type broadcast
```

在R3上配置Loopback 0和GigabitEthernet 0/0/0属于区域0，Serial 3/0/0属于区域2。

```
[R3]ospf 1 router-id 10.0.3.3
[R3-ospf-1]area 0
```

```
[R3-ospf-1-area-0.0.0.0]network 10.1.234.3 0.0.0.0
[R3-ospf-1-area-0.0.0.0]network 10.0.3.3 0.0.0.0
[R3-ospf-1-area-0.0.0.0]area 1
[R3-ospf-1-area-0.0.0.1]network 10.0.35.3 0.0.0.0
[R3-ospf-1-area-0.0.0.1]interface LoopBack 0
[R3-LoopBack0]ospf network-type broadcast
[R3-LoopBack0]quit
```

在R5上配置Serial 1/0/0属于区域1，Loopback 0不属于任何区域。

```
[R5]osp 1 router-id 10.0.5.5
[R5-ospf-1]area 1
[R5-ospf-1-area-0.0.0.1]network 10.0.35.5 0.0.0.0
```

配置完成后，在R1查看设备的路由表。

```
[R1]display ip routing-table
Route Flags: R - relay, D - download to fib
------------------------------------------------------------------------------
Routing Tables: Public
        Destinations : 14      Routes : 14

Destination/Mask    Proto   Pre  Cost     Flags NextHop        Interface

      10.0.1.0/24   Direct  0    0        D   10.0.1.1        LoopBack0
      10.0.1.1/32   Direct  0    0        D   127.0.0.1       InLoopBack0
    10.0.1.255/32   Direct  0    0        D   127.0.0.1       InLoopBack0
      10.0.2.0/24   OSPF    10   1        D   10.1.234.2    GigabitEthernet0/0/0
      10.0.3.0/24   OSPF    10   1        D   10.1.234.3    GigabitEthernet0/0/0
      10.0.4.0/24   OSPF    10   1        D   10.1.234.4    GigabitEthernet0/0/0
     10.0.35.0/24   OSPF    10   1563     D   10.1.234.3    GigabitEthernet0/0/0
    10.1.234.0/24   Direct  0    0        D   10.1.234.1    GigabitEthernet0/0/0
    10.1.234.1/32   Direct  0    0        D   127.0.0.1       InLoopBack0
  10.1.234.255/32   Direct  0    0        D   127.0.0.1       InLoopBack0
     127.0.0.0/8    Direct  0    0        D   127.0.0.1       InLoopBack0
     127.0.0.1/32   Direct  0    0        D   127.0.0.1       InLoopBack0
127.255.255.255/32  Direct  0    0        D   127.0.0.1       InLoopBack0
255.255.255.255/32  Direct  0    0        D   127.0.0.1       InLoopBack0
```

除了没有发布进OSPF的网络10.0.5.5/24，在R1上已拥有全网的路由表。

测试网络的连通性。

```
[R1]ping -c 1 10.0.2.2
  PING 10.0.2.2: 56  data bytes, press CTRL_C to break
```

```
    Reply from 10.0.2.2: bytes=56 Sequence=1 ttl=255 time=2 ms

  --- 10.0.2.2 ping statistics ---
    1 packet(s) transmitted
    1 packet(s) received
    0.00% packet loss
    round-trip min/avg/max = 2/2/2 ms

[R1]ping -c 1 10.0.4.4
  PING 10.0.4.4: 56  data bytes, press CTRL_C to break
    Reply from 10.0.4.4: bytes=56 Sequence=1 ttl=255 time=3 ms

  --- 10.0.4.4 ping statistics ---
    1 packet(s) transmitted
    1 packet(s) received
    0.00% packet loss
    round-trip min/avg/max = 3/3/3 ms

    [R3]ping -c 1 10.0.1.1
      PING 10.0.1.1: 56  data bytes, press CTRL_C to break
        Reply from 10.0.1.1: bytes=56 Sequence=1 ttl=255 time=3 ms

      --- 10.0.1.1 ping statistics ---
        1 packet(s) transmitted
        1 packet(s) received
        0.00% packet loss
        round-trip min/avg/max = 3/3/3 ms
```

使用**display ospf brief**命令查看路由器运行的基本OSPF信息。我们可以看到，由于R1的Loopback 0接口位于区域2中，所以R1成为了一台ABR。R1的GigabitEthernet 0/0/0接口所连接的网络为广播型网络，且R1为这个网段的DR。

```
[R1]display ospf brief

         OSPF Process 1 with Router ID 10.0.1.1
                 OSPF Protocol Information

 RouterID: 10.0.1.1         Border Router:  AREA
 Multi-VPN-Instance is not enabled
 Global DS-TE Mode: Non-Standard IETF Mode
 Graceful-restart capability: disabled
 Helper support capability  : not configured
 Spf-schedule-interval: max 10000ms, start 500ms, hold 1000ms
 Default ASE parameters: Metric: 1 Tag: 1 Type: 2
```

```
Route Preference: 10
ASE Route Preference: 150
SPF Computation Count: 26
RFC 1583 Compatible
Retransmission limitation is disabled
Area Count: 2   Nssa Area Count: 0
ExChange/Loading Neighbors: 0

Area: 0.0.0.0
Authtype: None   Area flag: Normal
SPF scheduled Count: 26
ExChange/Loading Neighbors: 0

Interface: 10.1.234.1 (GigabitEthernet0/0/0)
Cost: 1       State: DR       Type: Broadcast    MTU: 1500
Priority: 1
Designated Router: 10.1.234.1
Backup Designated Router: 10.1.234.2
Timers: Hello 10 , Dead 40 , Poll  120 , Retransmit 5 , Transmit Delay 1

Area: 0.0.0.2
Authtype: None   Area flag: Normal
SPF scheduled Count: 25
ExChange/Loading Neighbors: 0

Interface: 10.0.1.1 (LoopBack0)
Cost: 0       State: DR       Type: Broadcast    MTU: 1500
Priority: 1
Designated Router: 10.0.1.1
Backup Designated Router: 0.0.0.0
Timers: Hello 10 , Dead 40 , Poll  120 , Retransmit 5 , Transmit Delay 1
```

使用**display ospf peer brief**命令查看路由器的OSPF邻居关系建立情况。由于R1是DR，所以它与该网段的所有路由器形成邻接关系。在R3上查看邻居就可以发现R3和R4之间仅存在邻居关系，而没有邻接关系。

```
[R1]display ospf peer brief

       OSPF Process 1 with Router ID 10.0.1.1
               Peer Statistic Information
 ----------------------------------------------------------------------------
 Area Id         Interface                      Neighbor id     State
 0.0.0.0         GigabitEthernet0/0/0             10.0.2.2        Full
 0.0.0.0         GigabitEthernet0/0/0             10.0.3.3        Full
```

```
 0.0.0.0         GigabitEthernet0/0/0          10.0.4.4        Full
 ----------------------------------------------------------------------------

[R3]display ospf peer brief

       OSPF Process 1 with Router ID 10.0.3.3
              Peer Statistic Information
 ----------------------------------------------------------------------------
 Area Id         Interface                    Neighbor id     State
 0.0.0.0         GigabitEthernet0/0/0          10.0.1.1        Full
 0.0.0.0         GigabitEthernet0/0/0          10.0.2.2        Full
 0.0.0.0         GigabitEthernet0/0/0          10.0.4.4        2-Way
 0.0.0.1         Serial3/0/0                   10.0.5.5        Full
 ----------------------------------------------------------------------------
```

在R5上使用**display ospf lsdb**命令查看路由器的OSPF数据库信息。

```
[R5]display ospf lsdb

       OSPF Process 1 with Router ID 10.0.5.5
             Link State Database

                    Area: 0.0.0.1
 Type      LinkState ID      AdvRouter          Age  Len   Sequence   Metric
 Router    10.0.5.5          10.0.5.5          1182  48    80000002    1562
 Router    10.0.3.3          10.0.3.3          1183  48    80000002    1562
 Sum-Net   10.0.3.0          10.0.3.3          1429  28    80000001       0
 Sum-Net   10.0.2.0          10.0.3.3          1429  28    80000001       1
 Sum-Net   10.0.1.0          10.0.3.3          1429  28    80000001       1
 Sum-Net   10.1.234.0        10.0.3.3          1429  28    80000001       1
 Sum-Net   10.0.4.0          10.0.3.3          1430  28    80000001       1
```

可以看到由于在区域1中仅存在2台路由器，所以在R5的lsdb中，仅存在2条第一类LSA，剩余的5条第三类LSA是由R3向R5通告的区域间路由。

在R2上使用**display ospf lsdb**命令查看路由器的OSPF数据库信息。

```
[R2]display ospf lsdb

       OSPF Process 1 with Router ID 10.0.2.2
             Link State Database

                    Area: 0.0.0.0
 Type      LinkState ID      AdvRouter          Age  Len   Sequence   Metric
 Router    10.0.3.3          10.0.3.3             4  48   80000009       1
```

```
Router    10.0.4.4         10.0.4.4          150  48    80000009       1
Router    10.0.2.2         10.0.2.2          149  48    8000000C       1
Router    10.0.1.1         10.0.1.1          149  36    8000000B       1
Network   10.1.234.1       10.0.1.1          149  40    80000007       0
Sum-Net   10.0.35.0        10.0.3.3         1790  28    80000001    1562
Sum-Net   10.0.1.0         10.0.1.1          817  28    80000002       0
```

在R2上除了4条第一类LSA以外，还有一条第二类LSA。R2的GigabitEthernet 0/0/0所连接的是一个广播型网络，该网络上的DR会产生一条第二类LSA来描述所有的邻居。在这里可以从AdvRouter字段得知生成这条LSA的路由器是R1，符合R1是该网段DR的结果。

在R1上使用**display ospf lsdb**命令查看路由器的OSPF数据库信息。

```
[R1]display ospf lsdb

       OSPF Process 1 with Router ID 10.0.1.1
              Link State Database

                     Area: 0.0.0.0
Type      LinkState ID     AdvRouter          Age  Len   Sequence   Metric
Router    10.0.3.3         10.0.3.3          447  48    80000009       1
Router    10.0.4.4         10.0.4.4          592  48    80000009       1
Router    10.0.2.2         10.0.2.2          592  48    8000000C       1
Router    10.0.1.1         10.0.1.1          591  36    8000000B       1
Network   10.1.234.1       10.0.1.1          591  40    80000007       0
Sum-Net   10.0.35.0        10.0.3.3          434  28    80000002    1562
Sum-Net   10.0.1.0         10.0.1.1         1259  28    80000002       0

                     Area: 0.0.0.2
Type      LinkState ID     AdvRouter          Age  Len   Sequence   Metric
Router    10.0.1.1         10.0.1.1         1223  36    80000004       0
Sum-Net   10.0.35.0        10.0.1.1          433  28    80000002    1563
Sum-Net   10.0.3.0         10.0.1.1          541  28    80000002       1
Sum-Net   10.0.2.0         10.0.1.1          909  28    80000002       1
Sum-Net   10.1.234.0       10.0.1.1         1269  28    80000002       1
Sum-Net   10.0.4.0         10.0.1.1          711  28    80000002       1
```

由于R1的Loopback 0接口位于区域2中，所以R1上有2个区域的LSDB，分别是区域0和区域2的。

在R4上使用**display ospf lsdb**命令查看路由器的OSPF数据库信息。

```
[R4]display ospf lsdb
```

```
        OSPF Process 1 with Router ID 10.0.4.4
               Link State Database

                      Area: 0.0.0.0
 Type      LinkState ID      AdvRouter          Age  Len   Sequence   Metric
 Router    10.0.3.3          10.0.3.3           745  48    80000009       1
 Router    10.0.4.4          10.0.4.4           888  48    80000009       1
 Router    10.0.2.2          10.0.2.2           889  48    8000000C       1
 Router    10.0.1.1          10.0.1.1           889  36    8000000B       1
 Network   10.1.234.1        10.0.1.1           889  40    80000007       0
 Sum-Net   10.0.35.0         10.0.3.3           732  28    80000002    1562
 Sum-Net   10.0.1.0          10.0.1.1          1556  28    80000002       0
```

注意由于OSPF路由器的角色差异，OSPF链路状态数据库内容也会有所差异。对比分析R5、R2、R1与R4链路状态数据库的差异。

步骤三.　修改路由器 OSPF 接口优先级，影响 DR 选举

配置R3的G0/0/0接口优先级为255，确保R3成为10.1.234.0/24网段的DR。修改R2的G0/0/0接口优先级为254，确保R2成为10.1.234.0/24网段的BDR。修改R4的G0/0/0接口优先级为0，确保R4不参加DR/BDR选举，而成为10.1.234.0/24网段的DROther。

```
[R3]interface GigabitEthernet 0/0/0
[R3-GigabitEthernet0/0/0]ospf dr-priority 255

[R2]interface GigabitEthernet 0/0/0
[R2-GigabitEthernet0/0/0]ospf dr-priority 254

[R4]interface GigabitEthernet 0/0/0
[R4-GigabitEthernet0/0/0]ospf dr-priority 0
```

配置完成后，由于DR/BDR已经选举，并且DR/BDR角色不能抢占。所以必须关闭R1、R2、R3、R4的G0/0/0接口，并依次打开R3、R2、R1和R4的G0/0/0接口。

```
[R1-GigabitEthernet0/0/0]shutdown

[R2-GigabitEthernet0/0/0]shutdown

[R3-GigabitEthernet0/0/0]shutdown

[R4-GigabitEthernet0/0/0]shutdown
```

```
[R1-GigabitEthernet0/0/0]undo shutdown

[R2-GigabitEthernet0/0/0]undo shutdown

[R3-GigabitEthernet0/0/0]undo shutdown

[R4-GigabitEthernet0/0/0]undo shutdown
```

查看网段10.1.234.0/24网段的DR/BDR选举情况。

```
[R3]display ospf peer

       OSPF Process 1 with Router ID 10.0.3.3
             Neighbors

 Area 0.0.0.0 interface 10.1.234.3(GigabitEthernet0/0/0)'s neighbors
 Router ID: 10.0.1.1       Address: 10.1.234.1
   State: Full  Mode:Nbr is  Slave  Priority: 1
   DR: 10.1.234.3  BDR: 10.1.234.2  MTU: 0
   Dead timer due in 29  sec
   Retrans timer interval: 3
   Neighbor is up for 00:02:17
   Authentication Sequence: [ 0 ]

 Router ID: 10.0.2.2       Address: 10.1.234.2
   State: Full  Mode:Nbr is  Slave  Priority: 254
   DR: 10.1.234.3  BDR: 10.1.234.2  MTU: 0
   Dead timer due in 35  sec
   Retrans timer interval: 6
   Neighbor is up for 00:01:14
   Authentication Sequence: [ 0 ]

 Router ID: 10.0.4.4       Address: 10.1.234.4
   State: Full  Mode:Nbr is  Master  Priority: 0
   DR: 10.1.234.3  BDR: 10.1.234.2  MTU: 0
   Dead timer due in 32  sec
   Retrans timer interval: 3
   Neighbor is up for 00:01:26
   Authentication Sequence: [ 0 ]

             Neighbors

 Area 0.0.0.1 interface 10.0.35.3(Serial3/0/0)'s neighbors
```

```
 Router ID: 10.0.5.5        Address: 10.0.35.5
   State: Full  Mode:Nbr is  Master  Priority: 1
   DR: None   BDR: None   MTU: 0
   Dead timer due in 27  sec
   Retrans timer interval: 4
   Neighbor is up for 00:53:37
   Authentication Sequence: [ 0 ]
```

在重启接口后R3成为了该网段的DR，R2成为了BDR。

查看R4与R1的邻居关系。

```
[R4]display ospf peer 10.0.1.1

       OSPF Process 1 with Router ID 10.0.4.4
             Neighbors

 Area 0.0.0.0 interface 10.1.234.4(GigabitEthernet0/0/0)'s neighbors
 Router ID: 10.0.1.1        Address: 10.1.234.1
   State: 2-Way  Mode:Nbr is  Slave  Priority: 1
   DR: 10.1.234.3  BDR: 10.1.234.2  MTU: 0
   Dead timer due in 30  sec
   Retrans timer interval: 0
   Neighbor is up for 00:00:00
   Authentication Sequence: [ 0 ]
```

当邻居关系稳定以后，由于R1和R4均为DROther路由器，所以他们之间仅形成邻居关系，保持在2-way状态。

步骤四.　配置将直连路由汇总并引入到 OSPF 区域

R5的Loopback0接口不属于OSPF区域。将这条直连路由引入到OSPF区域。

```
[R5]ospf
[R5-ospf-1]import-route direct
```

在R1和R3上查看引入的外部路由。

```
[R1]display ip routing-table protocol ospf
Route Flags: R - relay, D - download to fib
------------------------------------------------------------------------------
Public routing table : OSPF
       Destinations : 6       Routes : 6
```

```
OSPF routing table status : <Active>
        Destinations : 6       Routes : 6

Destination/Mask   Proto   Pre  Cost    Flags NextHop        Interface

      10.0.2.0/24  OSPF    10   1         D   10.1.234.2    GigabitEthernet0/0/0
      10.0.3.0/24  OSPF    10   1         D   10.1.234.3    GigabitEthernet0/0/0
      10.0.4.0/24  OSPF    10   1         D   10.1.234.4    GigabitEthernet0/0/0
      10.0.5.0/24  O_ASE   150  1         D   10.1.234.3    GigabitEthernet0/0/0
     10.0.35.0/24  OSPF    10   1563      D   10.1.234.3    GigabitEthernet0/0/0
     10.0.35.3/32  O_ASE   150  1         D   10.1.234.3    GigabitEthernet0/0/0

OSPF routing table status : <Inactive>
        Destinations : 0       Routes : 0

[R3]display ip routing-table protocol ospf
Route Flags: R - relay, D - download to fib
------------------------------------------------------------------------------
Public routing table : OSPF
        Destinations : 5       Routes : 5

OSPF routing table status : <Active>
        Destinations : 4       Routes : 4

Destination/Mask   Proto   Pre  Cost    Flags NextHop        Interface

      10.0.1.0/24  OSPF    10   1         D   10.1.234.1    GigabitEthernet0/0/0
      10.0.2.0/24  OSPF    10   1         D   10.1.234.2    GigabitEthernet0/0/0
      10.0.4.0/24  OSPF    10   1         D   10.1.234.4    GigabitEthernet0/0/0
      10.0.5.0/24  O_ASE   150  1         D   10.0.35.5       Serial3/0/0

OSPF routing table status : <Inactive>
        Destinations : 1       Routes : 1

Destination/Mask    Proto   Pre  Cost     Flags NextHop        Interface

     10.0.35.3/32  O_ASE   150  1            10.0.35.5       Serial3/0/0
```

在R1和R3上均看到2条外部路由，分别是10.0.5.0/24和10.0.35.3/32。10.0.5.0/24为R5的Loopback接口，但为什么还有一条10.0.35.3/32呢？

查看R5的路由表，由于R3和R5之间是以PPP的形式封装的，R3的Serial 3/0/0的接口地址会以直连路由的形式出现在R5的路由表里，所以在R5上运行**import-route direct**以后该路由条目也被发布出去了。

```
[R5]display  ip routing-table
Route Flags: R - relay, D - download to fib
------------------------------------------------------------------------------
Routing Tables: Public
        Destinations : 16      Routes : 16

Destination/Mask     Proto   Pre  Cost     Flags NextHop         Interface
     10.0.35.0/24   Direct  0    0          D   10.0.35.5       Serial1/0/0
     10.0.35.3/32   Direct  0    0          D   10.0.35.3       Serial1/0/0
     10.0.35.5/32   Direct  0    0          D   127.0.0.1       InLoopBack0
   10.0.35.255/32   Direct  0    0          D   127.0.0.1       InLoopBack0
```

最后测试网络连通性。

```
[R1]ping -c 1 10.0.5.5
  PING 10.0.5.5: 56  data bytes, press CTRL_C to break
    Reply from 10.0.5.5: bytes=56 Sequence=1 ttl=254 time=41 ms

  --- 10.0.5.5 ping statistics ---
    1 packet(s) transmitted
    1 packet(s) received
    0.00% packet loss
    round-trip min/avg/max = 41/41/41 ms
```

在R1上查看OSPF外部路由在链路状态数据库中的情况。我们可以看到，R1的LSDB中一共有3条外部路由：10.0.5.0/24、10.0.35.0/24、10.0.35.3/32。

在R1的路由表中看见的外部路由只有2条，另一条不见了。

```
 [R1]display ospf lsdb ase

        OSPF Process 1 with Router ID 10.0.1.1
                Link State Database


  Type      : External
  Ls id     : 10.0.5.0
  Adv rtr    : 10.0.5.5
  Ls age     : 834
  Len       : 36
  Options    :  E
  seq#      : 80000001
  chksum     : 0xa904
  Net mask  : 255.255.255.0
  TOS 0  Metric: 1
```

```
 E type    : 2
 Forwarding Address : 0.0.0.0
 Tag       : 1
 Priority  : Low

 Type      : External
 Ls id     : 10.0.35.0
 Adv rtr   : 10.0.5.5
 Ls age    : 1342
 Len       : 36
 Options   :  E
 seq#      : 80000001
 chksum    : 0x5e31
 Net mask  : 255.255.255.0
 TOS 0  Metric: 1
 E type    : 2
 Forwarding Address : 0.0.0.0
 Tag       : 1
 Priority  : Low

 Type      : External
 Ls id     : 10.0.35.3
 Adv rtr   : 10.0.5.5
 Ls age    : 1344
 Len       : 36
 Options   :  E
 seq#      : 80000001
 chksum    : 0x404c
 Net mask  : 255.255.255.255
 TOS 0  Metric: 1
 E type    : 2
 Forwarding Address : 0.0.0.0
 Tag       : 1
 Priority  : Medium
```

经过比较后，可以发现10.0.35.0/24这条路由是以内部路由的形式出现在路由表中的。

检查R1的LSDB中得第三类LSA就可以看到这个条目：10.0.35.0/24。

```
[R1]display ospf lsdb summary 10.0.35.0


       OSPF Process 1 with Router ID 10.0.1.1
                     Area: 0.0.0.0
```

```
             Link State Database


  Type      : Sum-Net
  Ls id     : 10.0.35.0
  Adv rtr    : 10.0.3.3
  Ls age    : 136
  Len       : 28
  Options    :  E
  seq#      : 80000004
  chksum    : 0x1ae2
  Net mask  : 255.255.255.0
  Tos 0  metric: 1562
  Priority  : Low
```

可以看出，当第三类和第五类LSA通告路由的网络位和掩码相同的情况下，OSPF优选第三类LSA通告的路由加到路由表里。

步骤五.　查看各种类型的 LSA

在R1上查看一类LSA 10.0.1.0在Area0和Area2的详细内容。

```
[R1]display ospf lsdb router 10.0.1.1

       OSPF Process 1 with Router ID 10.0.1.1
                    Area: 0.0.0.0
             Link State Database


  Type        : Router
  Ls id       : 10.0.1.1
  Adv rtr     : 10.0.1.1
  Ls age      : 591
  Len         : 36
  Options     :  ABR  E
  seq#        : 8000001e
  chksum      : 0xbc70
  Link count: 1
   * Link ID: 10.1.234.3
     Data     : 10.1.234.1
     Link Type: TransNet
     Metric : 1
                    Area: 0.0.0.2
```

```
             Link State Database


 Type       : Router
 Ls id      : 10.0.1.1
 Adv rtr    : 10.0.1.1
 Ls age     : 627
 Len        : 36
 Options    :  ABR  E
 seq#       : 80000008
 chksum     : 0x1018
 Link count: 1
  * Link ID: 10.0.1.0
    Date    : 255.255.255.0
    Link Type: StubNet
    Metric  : 0
    Priority: Low
```

对于一类LSA来说，Ls id字段表示生成这条LSA的路由器的Router ID。

R1共生成了两条第一类LSA，一条在区域0中泛洪。R1在区域0中与一个Transit网段相连，所以Link Type字段为TransNet。对于TransNet，Link ID字段为该网段上DR的接口IP地址，Data字段为本地接口的IP地址。

第二条一类LSA是R1向区域2中泛洪的，R1与区域2通过Loopback接口相连。对于Loopback接口，Link Type为StubNet，此时Link ID表示该Stub网段的IP网络地址，Data表示该Stub网段的网络掩码。

在R2、R3和R4上分别查看二类LSA 10.1.234.0在Area0的详细内容。

```
[R2]display ospf lsdb network 10.1.234.3

       OSPF Process 1 with Router ID 10.0.2.2
                    Area: 0.0.0.0
             Link State Database


 Type      : Network
 Ls id     : 10.1.234.3
 Adv rtr    : 10.0.3.3
 Ls age    : 115
 Len       : 40
 Options    :  E
 seq#      : 8000000f
 chksum    : 0x807e
```

```
  Net mask  : 255.255.255.0
  Priority  : Low
    Attached Router    10.0.3.3
    Attached Router    10.0.1.1
    Attached Router    10.0.2.2
    Attached Router    10.0.4.4
```

发现在R2、R3和R4上看到的这条LSA是一样的。

同样，可以通过Adv rtr字段得知这条LSA是由R3生成的。第二类LSA 的Ls id描述的是该网段上DR的接口IP地址，Attached Router为该网段上所有路由器的Router ID。

在R1和R3上查看三类LSA 10.0.35.0/24在Area0的详细内容。

```
[R3]display ospf lsdb summary 10.0.35.0

        OSPF Process 1 with Router ID 10.0.3.3
                        Area: 0.0.0.0
                Link State Database


  Type      : Sum-Net
  Ls id     : 10.0.35.0
  Adv rtr   : 10.0.3.3
  Ls age    : 591
  Len       : 28
  Options   :  E
  seq#      : 8000000a
  chksum    : 0xee8
  Net mask  : 255.255.255.0
  Tos 0  metric: 1562
  Priority  : Low
```

从输出中可以看到该路由是由R3向区域0中通告的。Ls id就是通告的目的网段的网络地址，Net mask描述了目的网段的掩码信息。

```
[R1]display ospf lsdb summary 10.0.35.0

        OSPF Process 1 with Router ID 10.0.1.1
                        Area: 0.0.0.0
                Link State Database


  Type      : Sum-Net
```

```
  Ls id     : 10.0.35.0
  Adv rtr   : 10.0.3.3
  Ls age    : 136
  Len       : 28
  Options   :  E
  seq#      : 80000004
  chksum    : 0x1ae2
  Net mask  : 255.255.255.0
  Tos 0  metric: 1562
  Priority  : Low
                   Area: 0.0.0.2
             Link State Database


  Type      : Sum-Net
  Ls id     : 10.0.35.0
  Adv rtr   : 10.0.1.1
  Ls age    : 382
  Len       : 28
  Options   :  E
  seq#      : 80000002
  chksum    : 0x42bf
  Net mask  : 255.255.255.0
  Tos 0  metric: 1563
  Priority  : Low
```

在R1上共有2条描述10.0.35.0/24的第三类LSA。其中，从Adv rtr字段我们可以得知区域0中这条LSA是R3产生的。由于R1本身也是一台ABR，所以R1收到这条LSA以后又产生了一条LSA，向区域2中通告。

在R1上查看四类LSA 10.0.5.0在Area2的详细内容。第四类LSA用于描述如何到达ASBR。

```
[R1]display ospf lsdb asbr 10.0.5.5

       OSPF Process 1 with Router ID 10.0.1.1
                   Area: 0.0.0.0
             Link State Database


  Type      : Sum-Asbr
  Ls id     : 10.0.5.5
  Adv rtr   : 10.0.3.3
  Ls age    : 1119
```

```
 Len       : 28
 Options    :  E
 seq#      : 80000008
 chksum    : 0x1df3
 Tos 0  metric: 1562
                   Area: 0.0.0.2
             Link State Database


 Type      : Sum-Asbr
 Ls id     : 10.0.5.5
 Adv rtr    : 10.0.1.1
 Ls age    : 1118
 Len       : 28
 Options    :  E
 seq#      : 80000008
 chksum    : 0x41d2
 Tos 0  metric: 1563
```

从输出中可以看到，R1从R3收到了一条第四类LSA。Ls id用于描述ASBR的Router ID。由于这类LSA不能跨区域泛洪，所以R1又生成了一条第四类LSA向区域2中泛洪。

在R2、R4以及R3的区域0的LSDB中均存在这条LSA，因为这些路由器和ASBR（R5）不在同一个区域，他们需要通过第四类LSA来得知ASBR的位置。

```
[R2]display ospf lsdb asbr

       OSPF Process 1 with Router ID 10.0.2.2
                   Area: 0.0.0.0
             Link State Database


 Type      : Sum-Asbr
 Ls id     : 10.0.5.5
 Adv rtr    : 10.0.3.3
 Ls age    : 1676
 Len       : 28
 Options    :  E
 seq#      : 80000008
 chksum    : 0x1df3
 Tos 0  metric: 1562
```

在区域1中就没有这条第四类LSA，同一个区域的路由器，不需要依赖这条

LSA来得知ASBR的位置。

步骤六. 观察 LSR、LSU 和 LSAck

我们首先观察OSPF的Update数据包及ACK数据包发送的过程。在R1上打开**debugging ospf packet update**、**debugging ospf packet ack**。

```
<R3>terminal monitor
% Current terminal monitor is on
<R3>terminal debugging
% Current terminal debugging is on
<R3>debugging ospf packet update
  OSPF Link State Update PACKET debugging switch is on
<R3>debugging ospf packet ack
  OSPF Link State Acknowledgment PACKET debugging switch is on
```

默认情况下，网络稳定运行，OSPF路由器每30分钟更新一次。为触发查询和更新信息，我们将R3的Loopback 0接口删除。

```
[R3]undo interface LoopBack 0
```

我们可以观察到首先在R1上接收到10.1.234.3发来的Update消息，消息的目的地址为224.0.0.5（即所有OSPF路由器），描述了一个网段（# Links: 1），后面有该网段的LinkID和LinkData。

```
Nov 24 2011 16:08:19.740.1+00:00 R1 RM/6/RMDEBUG:
 FileID: 0xd0178024 Line: 2178 Level: 0x20
 OSPF 1: RECV Packet. Interface: GigabitEthernet0/0/0
Nov 24 2011 16:08:19.740.2+00:00 R1 RM/6/RMDEBUG:  Source Address: 10.1.234.3
Nov 24 2011 16:08:19.740.3+00:00 R1 RM/6/RMDEBUG:  Destination Address: 224.0.0.5
Nov 24 2011 16:08:19.740.4+00:00 R1 RM/6/RMDEBUG:  Ver# 2, Type: 4 (Link-State
Update)
Nov 24 2011 16:08:19.740.5+00:00 R1 RM/6/RMDEBUG:  Length: 64, Router: 10.0.3.3
Nov 24 2011 16:08:19.740.6+00:00 R1 RM/6/RMDEBUG:  Area: 0.0.0.0, Chksum: 3671
Nov 24 2011 16:08:19.740.7+00:00 R1 RM/6/RMDEBUG:  AuType: 00
Nov 24 2011 16:08:19.740.8+00:00 R1 RM/6/RMDEBUG:  Key(ascii): 0 0 0 0 0 0 0 0
Nov 24 2011 16:08:19.740.9+00:00 R1 RM/6/RMDEBUG:  # LSAS: 1
Nov 24 2011 16:08:19.740.10+00:00 R1 RM/6/RMDEBUG:  LSA Type 1
Nov 24 2011 16:08:19.740.11+00:00 R1 RM/6/RMDEBUG:    LS ID: 10.0.3.3
Nov 24 2011 16:08:19.740.12+00:00 R1 RM/6/RMDEBUG:    Adv Rtr: 10.0.3.3
Nov 24 2011 16:08:19.740.13+00:00 R1 RM/6/RMDEBUG:    LSA Age: 1
Nov 24 2011 16:08:19.740.14+00:00 R1 RM/6/RMDEBUG:    Options: ExRouting:ON
Nov 24 2011 16:08:19.740.15+00:00 R1 RM/6/RMDEBUG:    Length: 36, Seq# 8000004f
Nov 24 2011 16:08:19.740.16+00:00 R1 RM/6/RMDEBUG:    CheckSum: 32bf
```

```
Nov 24 2011 16:08:19.740.17+00:00 R1 RM/6/RMDEBUG:    NtBit: 0  VBit: 0 EBit: 0
BBit: 1
Nov 24 2011 16:08:19.740.18+00:00 R1 RM/6/RMDEBUG:    # Links: 1
Nov 24 2011 16:08:19.740.19+00:00 R1 RM/6/RMDEBUG:    LinkID: 10.1.234.3
Nov 24 2011 16:08:19.740.20+00:00 R1 RM/6/RMDEBUG:      LinkData: 10.1.234.3
Nov 24 2011 16:08:19.740.21+00:00 R1 RM/6/RMDEBUG:      LinkType: 2
Nov 24 2011 16:08:19.740.22+00:00 R1 RM/6/RMDEBUG:      TOS# 0 Metric 1
```

接下来R1收到了一个ACK的报文，从内容看到该报文为BDR发送的ACK报文，发送的目的地址为224.0.0.5，所以R1也收到了这个报文。从该报文的序列号（Seq# 8000004f）我们可以得知，该报文为刚才Update报文的回应。

```
Nov 24 2011 16:08:20.360.1+00:00 R1 RM/6/RMDEBUG:
 FileID: 0xd0178024 Line: 2178 Level: 0x20
 OSPF 1: RECV Packet. Interface: GigabitEthernet0/0/0
Nov 24 2011 16:08:20.360.2+00:00 R1 RM/6/RMDEBUG:  Source Address: 10.1.234.2
Nov 24 2011 16:08:20.360.3+00:00 R1 RM/6/RMDEBUG:  Destination Address: 224.0.0.5
Nov 24 2011 16:08:20.360.4+00:00 R1 RM/6/RMDEBUG:  Ver# 2, Type: 5 (Link-State
Ack)
Nov 24 2011 16:08:20.360.5+00:00 R1 RM/6/RMDEBUG:  Length: 64, Router: 10.0.2.2
Nov 24 2011 16:08:20.360.6+00:00 R1 RM/6/RMDEBUG:  Area: 0.0.0.0, Chksum: 9b07
Nov 24 2011 16:08:20.360.7+00:00 R1 RM/6/RMDEBUG:  AuType: 00
Nov 24 2011 16:08:20.360.8+00:00 R1 RM/6/RMDEBUG:  Key(ascii): 0 0 0 0 0 0 0 0
Nov 24 2011 16:08:20.360.9+00:00 R1 RM/6/RMDEBUG:  # LSA Headers: 2
Nov 24 2011 16:08:20.360.10+00:00 R1 RM/6/RMDEBUG:  LSA Type 1
Nov 24 2011 16:08:20.360.11+00:00 R1 RM/6/RMDEBUG:    LS ID: 10.0.3.3
Nov 24 2011 16:08:20.360.12+00:00 R1 RM/6/RMDEBUG:    Adv Rtr: 10.0.3.3
Nov 24 2011 16:08:20.360.13+00:00 R1 RM/6/RMDEBUG:    LSA Age: 6
Nov 24 2011 16:08:20.360.14+00:00 R1 RM/6/RMDEBUG:    Options: ExRouting:ON
Nov 24 2011 16:08:20.360.15+00:00 R1 RM/6/RMDEBUG:    Length: 36, Seq# 8000004f
Nov 24 2011 16:08:20.360.16+00:00 R1 RM/6/RMDEBUG:    CheckSum: 32bf
```

最后是R1自己发送的ACK报文。报文源地址为R1 GigabitEthernet 0/0/0的接口地址，目的地址为224.0.0.6。该报文是发送给DR和BDR的。该报文的序列号也是8000004f。

```
Nov 24 2011 16:08:20.650.1+00:00 R1 RM/6/RMDEBUG:
 FileID: 0xd0178025 Line: 4383 Level: 0x20
 OSPF 1: SEND Packet. Interface: GigabitEthernet0/0/0
Nov 24 2011 16:08:20.650.2+00:00 R1 RM/6/RMDEBUG:  Source Address: 10.1.234.1
Nov 24 2011 16:08:20.650.3+00:00 R1 RM/6/RMDEBUG:  Destination Address: 224.0.0.6
Nov 24 2011 16:08:20.650.4+00:00 R1 RM/6/RMDEBUG:  Ver# 2, Type: 5 (Link-State
Ack)
Nov 24 2011 16:08:20.650.5+00:00 R1 RM/6/RMDEBUG:  Length: 44, Router: 10.0.1.1
```

```
Nov 24 2011 16:08:20.650.6+00:00 R1 RM/6/RMDEBUG:  Area: 0.0.0.0, Chksum: 2392
Nov 24 2011 16:08:20.650.7+00:00 R1 RM/6/RMDEBUG:  AuType: 00
Nov 24 2011 16:08:20.650.8+00:00 R1 RM/6/RMDEBUG:  Key(ascii): 0 0 0 0 0 0 0 0
Nov 24 2011 16:08:20.650.9+00:00 R1 RM/6/RMDEBUG:  # LSA Headers: 1
Nov 24 2011 16:08:20.650.10+00:00 R1 RM/6/RMDEBUG:  LSA Type 1
Nov 24 2011 16:08:20.650.11+00:00 R1 RM/6/RMDEBUG:    LS ID: 10.0.3.3
Nov 24 2011 16:08:20.650.12+00:00 R1 RM/6/RMDEBUG:    Adv Rtr: 10.0.3.3
Nov 24 2011 16:08:20.650.13+00:00 R1 RM/6/RMDEBUG:    LSA Age: 2
Nov 24 2011 16:08:20.650.14+00:00 R1 RM/6/RMDEBUG:    Options: ExRouting:ON
Nov 24 2011 16:08:20.650.15+00:00 R1 RM/6/RMDEBUG:    Length: 36, Seq# 8000004f
Nov 24 2011 16:08:20.650.16+00:00 R1 RM/6/RMDEBUG:    CheckSum: 32bf
```

接下来恢复R3上删除的Loopback0接口。

```
[R3]interface loopback 0
[R3-LoopBack0]ip address 10.0.3.3 24
```

和刚才一样，R1首先收到来自R3的Update报文，但这次在报文中通告了一个新的网段，所以# Links这里值为2，后面有新通告的网段的网络号和掩码。

```
<R1>
Nov 24 2011 16:13:50.110.1+00:00 R1 RM/6/RMDEBUG:
 FileID: 0xd0178024 Line: 2178 Level: 0x20
 OSPF 1: RECV Packet. Interface: GigabitEthernet0/0/0
Nov 24 2011 16:13:50.110.2+00:00 R1 RM/6/RMDEBUG:  Source Address: 10.1.234.3
Nov 24 2011 16:13:50.110.3+00:00 R1 RM/6/RMDEBUG:  Destination Address: 224.0.0.5
Nov 24 2011 16:13:50.110.4+00:00 R1 RM/6/RMDEBUG:  Ver# 2, Type: 4 (Link-State
Update)
Nov 24 2011 16:13:50.110.5+00:00 R1 RM/6/RMDEBUG:  Length: 76, Router: 10.0.3.3
Nov 24 2011 16:13:50.110.6+00:00 R1 RM/6/RMDEBUG:  Area: 0.0.0.0, Chksum: 8516
Nov 24 2011 16:13:50.110.7+00:00 R1 RM/6/RMDEBUG:  AuType: 00
Nov 24 2011 16:13:50.110.8+00:00 R1 RM/6/RMDEBUG:  Key(ascii): 0 0 0 0 0 0 0 0
Nov 24 2011 16:13:50.110.9+00:00 R1 RM/6/RMDEBUG:  # LSAS: 1
Nov 24 2011 16:13:50.110.10+00:00 R1 RM/6/RMDEBUG:  LSA Type 1
Nov 24 2011 16:13:50.110.11+00:00 R1 RM/6/RMDEBUG:    LS ID: 10.0.3.3
Nov 24 2011 16:13:50.110.12+00:00 R1 RM/6/RMDEBUG:    Adv Rtr: 10.0.3.3
Nov 24 2011 16:13:50.110.13+00:00 R1 RM/6/RMDEBUG:    LSA Age: 1
Nov 24 2011 16:13:50.110.14+00:00 R1 RM/6/RMDEBUG:    Options: ExRouting:ON
Nov 24 2011 16:13:50.110.15+00:00 R1 RM/6/RMDEBUG:    Length: 48, Seq# 80000056
Nov 24 2011 16:13:50.110.16+00:00 R1 RM/6/RMDEBUG:    CheckSum: d3f6
Nov 24 2011 16:13:50.110.17+00:00 R1 RM/6/RMDEBUG:    NtBit: 0  VBit: 0 EBit: 0
BBit: 1
Nov 24 2011 16:13:50.110.18+00:00 R1 RM/6/RMDEBUG:    # Links: 2
Nov 24 2011 16:13:50.110.19+00:00 R1 RM/6/RMDEBUG:    LinkID: 10.1.234.3
```

```
Nov 24 2011 16:13:50.110.20+00:00 R1 RM/6/RMDEBUG:     LinkData: 10.1.234.3
Nov 24 2011 16:13:50.110.21+00:00 R1 RM/6/RMDEBUG:     LinkType: 2
Nov 24 2011 16:13:50.110.22+00:00 R1 RM/6/RMDEBUG:     TOS# 0 Metric 1
Nov 24 2011 16:13:50.110.23+00:00 R1 RM/6/RMDEBUG:   LinkID: 10.0.3.3
Nov 24 2011 16:13:50.110.24+00:00 R1 RM/6/RMDEBUG:   LinkData: 255.255.255.255
Nov 24 2011 16:13:50.110.25+00:00 R1 RM/6/RMDEBUG:     LinkType: 3
Nov 24 2011 16:13:50.110.26+00:00 R1 RM/6/RMDEBUG:     TOS# 0 Metric 0
Nov 24 2011 16:13:50.110.27+00:00 R1 RM/6/RMDEBUG:
Nov 24 2011 16:13:50.360.1+00:00 R1 RM/6/RMDEBUG:
```

R1首先收到BDR的ACK报文。

```
 FileID: 0xd0178024 Line: 2178 Level: 0x20
 OSPF 1: RECV Packet. Interface: GigabitEthernet0/0/0
Nov 24 2011 16:13:50.360.2+00:00 R1 RM/6/RMDEBUG:  Source Address: 10.1.234.2
Nov 24 2011 16:13:50.360.3+00:00 R1 RM/6/RMDEBUG:  Destination Address: 224.0.0.5
Nov 24 2011 16:13:50.360.4+00:00 R1 RM/6/RMDEBUG:  Ver# 2, Type: 5 (Link-State
Ack)
Nov 24 2011 16:13:50.360.5+00:00 R1 RM/6/RMDEBUG:  Length: 44, Router: 10.0.2.2
Nov 24 2011 16:13:50.360.6+00:00 R1 RM/6/RMDEBUG:  Area: 0.0.0.0, Chksum: 8147
Nov 24 2011 16:13:50.360.7+00:00 R1 RM/6/RMDEBUG:  AuType: 00
Nov 24 2011 16:13:50.360.8+00:00 R1 RM/6/RMDEBUG:  Key(ascii): 0 0 0 0 0 0 0 0
Nov 24 2011 16:13:50.360.9+00:00 R1 RM/6/RMDEBUG:  # LSA Headers: 1
Nov 24 2011 16:13:50.360.10+00:00 R1 RM/6/RMDEBUG:  LSA Type 1
Nov 24 2011 16:13:50.360.11+00:00 R1 RM/6/RMDEBUG:    LS ID: 10.0.3.3
Nov 24 2011 16:13:50.360.12+00:00 R1 RM/6/RMDEBUG:    Adv Rtr: 10.0.3.3
Nov 24 2011 16:13:50.360.13+00:00 R1 RM/6/RMDEBUG:    LSA Age: 1
Nov 24 2011 16:13:50.360.14+00:00 R1 RM/6/RMDEBUG:    Options: ExRouting:ON
Nov 24 2011 16:13:50.360.15+00:00 R1 RM/6/RMDEBUG:    Length: 48, Seq# 80000056
Nov 24 2011 16:13:50.360.16+00:00 R1 RM/6/RMDEBUG:    CheckSum: d3f6
Nov 24 2011 16:13:50.360.17+00:00 R1 RM/6/RMDEBUG:
Nov 24 2011 16:13:50.570.1+00:00 R1 RM/6/RMDEBUG:
```

最后是R1自己发送的ACK报文。

```
 FileID: 0xd0178025 Line: 4383 Level: 0x20
 OSPF 1: SEND Packet. Interface: GigabitEthernet0/0/0
Nov 24 2011 16:13:50.570.2+00:00 R1 RM/6/RMDEBUG:  Source Address: 10.1.234.1
Nov 24 2011 16:13:50.570.3+00:00 R1 RM/6/RMDEBUG:  Destination Address: 224.0.0.6
Nov 24 2011 16:13:50.570.4+00:00 R1 RM/6/RMDEBUG:  Ver# 2, Type: 5 (Link-State
Ack)
Nov 24 2011 16:13:50.570.5+00:00 R1 RM/6/RMDEBUG:  Length: 44, Router: 10.0.1.1
Nov 24 2011 16:13:50.570.6+00:00 R1 RM/6/RMDEBUG:  Area: 0.0.0.0, Chksum: 8248
Nov 24 2011 16:13:50.570.7+00:00 R1 RM/6/RMDEBUG:  AuType: 00
```

```
Nov 24 2011 16:13:50.570.8+00:00 R1 RM/6/RMDEBUG:  Key(ascii): 0 0 0 0 0 0 0 0
Nov 24 2011 16:13:50.570.9+00:00 R1 RM/6/RMDEBUG:  # LSA Headers: 1
Nov 24 2011 16:13:50.570.10+00:00 R1 RM/6/RMDEBUG:  LSA Type 1
Nov 24 2011 16:13:50.570.11+00:00 R1 RM/6/RMDEBUG:   LS ID: 10.0.3.3
Nov 24 2011 16:13:50.570.12+00:00 R1 RM/6/RMDEBUG:   Adv Rtr: 10.0.3.3
Nov 24 2011 16:13:50.570.13+00:00 R1 RM/6/RMDEBUG:   LSA Age: 1
Nov 24 2011 16:13:50.570.14+00:00 R1 RM/6/RMDEBUG:   Options: ExRouting:ON
Nov 24 2011 16:13:50.570.15+00:00 R1 RM/6/RMDEBUG:   Length: 48, Seq# 80000056
Nov 24 2011 16:13:50.570.16+00:00 R1 RM/6/RMDEBUG:   CheckSum: d3f6
```

在下面一个步骤中我们看Request报文。正常情况下，路由器不会主动发送该报文，为观察该报文的发送，我们将R1的OSPF进程重启。首先在路由器上观察到的是R1向R2发起了LS Request。

```
<R1>reset ospf process
Warning: The OSPF process will be reset. Continue? [Y/N]:y
Nov 24 2011 16:31:42.270.1+00:00 R1 RM/6/RMDEBUG:
 FileID: 0xd0178025 Line: 2842 Level: 0x20
 OSPF 1: SEND Packet. Interface: GigabitEthernet0/0/0
Nov 24 2011 16:31:42.270.2+00:00 R1 RM/6/RMDEBUG:  Source Address: 10.1.234.1
Nov 24 2011 16:31:42.270.3+00:00 R1 RM/6/RMDEBUG:  Destination Address:
10.1.234.2
Nov 24 2011 16:31:42.270.4+00:00 R1 RM/6/RMDEBUG:  Ver# 2, Type: 3 (Link-State
Req)
Nov 24 2011 16:31:42.270.5+00:00 R1 RM/6/RMDEBUG:  Length: 144, Router: 10.0.1.1
Nov 24 2011 16:31:42.270.6+00:00 R1 RM/6/RMDEBUG:  Area: 0.0.0.0, Chksum: a316
Nov 24 2011 16:31:42.270.7+00:00 R1 RM/6/RMDEBUG:  AuType: 00
Nov 24 2011 16:31:42.270.8+00:00 R1 RM/6/RMDEBUG:  Key(ascii): 0 0 0 0 0 0 0 0
Nov 24 2011 16:31:42.270.9+00:00 R1 RM/6/RMDEBUG:  # Requesting LSAs: 10
Nov 24 2011 16:31:42.270.10+00:00 R1 RM/6/RMDEBUG:  LSA Type 1
Nov 24 2011 16:31:42.270.11+00:00 R1 RM/6/RMDEBUG:   LS ID: 10.0.1.1
Nov 24 2011 16:31:42.270.12+00:00 R1 RM/6/RMDEBUG:   Adv Rtr: 10.0.1.1
Nov 24 2011 16:31:42.270.13+00:00 R1 RM/6/RMDEBUG:  LSA Type 1
Nov 24 2011 16:31:42.270.14+00:00 R1 RM/6/RMDEBUG:   LS ID: 10.0.3.3
Nov 24 2011 16:31:42.270.15+00:00 R1 RM/6/RMDEBUG:   Adv Rtr: 10.0.3.3
Nov 24 2011 16:31:42.280.1+00:00 R1 RM/6/RMDEBUG:  LSA Type 1
Nov 24 2011 16:31:42.280.2+00:00 R1 RM/6/RMDEBUG:   LS ID: 10.0.4.4
Nov 24 2011 16:31:42.280.3+00:00 R1 RM/6/RMDEBUG:   Adv Rtr: 10.0.4.4
Nov 24 2011 16:31:42.280.4+00:00 R1 RM/6/RMDEBUG:  LSA Type 2
Nov 24 2011 16:31:42.280.5+00:00 R1 RM/6/RMDEBUG:   LS ID: 10.1.234.3
Nov 24 2011 16:31:42.280.6+00:00 R1 RM/6/RMDEBUG:   Adv Rtr: 10.0.3.3
Nov 24 2011 16:31:42.280.7+00:00 R1 RM/6/RMDEBUG:  LSA Type 3
Nov 24 2011 16:31:42.280.8+00:00 R1 RM/6/RMDEBUG:   LS ID: 10.0.35.0
Nov 24 2011 16:31:42.280.9+00:00 R1 RM/6/RMDEBUG:   Adv Rtr: 10.0.3.3
```

```
Nov 24 2011 16:31:42.280.10+00:00 R1 RM/6/RMDEBUG:  LSA Type 3
Nov 24 2011 16:31:42.280.11+00:00 R1 RM/6/RMDEBUG:    LS ID: 10.0.1.0
Nov 24 2011 16:31:42.280.12+00:00 R1 RM/6/RMDEBUG:    Adv Rtr: 10.0.1.1
Nov 24 2011 16:31:42.280.13+00:00 R1 RM/6/RMDEBUG:  LSA Type 4
Nov 24 2011 16:31:42.280.14+00:00 R1 RM/6/RMDEBUG:    LS ID: 10.0.5.5
Nov 24 2011 16:31:42.280.15+00:00 R1 RM/6/RMDEBUG:    Adv Rtr: 10.0.3.3
Nov 24 2011 16:31:42.280.16+00:00 R1 RM/6/RMDEBUG:  LSA Type 5
Nov 24 2011 16:31:42.280.17+00:00 R1 RM/6/RMDEBUG:    LS ID: 10.0.35.0
Nov 24 2011 16:31:42.280.18+00:00 R1 RM/6/RMDEBUG:    Adv Rtr: 10.0.5.5
Nov 24 2011 16:31:42.280.19+00:00 R1 RM/6/RMDEBUG:  LSA Type 5
Nov 24 2011 16:31:42.280.20+00:00 R1 RM/6/RMDEBUG:    LS ID: 10.0.35.3
Nov 24 2011 16:31:42.280.21+00:00 R1 RM/6/RMDEBUG:    Adv Rtr: 10.0.5.5
Nov 24 2011 16:31:42.280.22+00:00 R1 RM/6/RMDEBUG:  LSA Type 5
Nov 24 2011 16:31:42.280.23+00:00 R1 RM/6/RMDEBUG:    LS ID: 10.0.5.0
Nov 24 2011 16:31:42.280.24+00:00 R1 RM/6/RMDEBUG:    Adv Rtr: 10.0.5.5
```

随后R1收到了来自R3的LS Request。

```
Nov 24 2011 16:31:48.320.1+00:00 R1 RM/6/RMDEBUG:
 FileID: 0xd0178024 Line: 2178 Level: 0x20
 OSPF 1: RECV Packet. Interface: GigabitEthernet0/0/0
Nov 24 2011 16:31:48.320.2+00:00 R1 RM/6/RMDEBUG:  Source Address: 10.1.234.3
Nov 24 2011 16:31:48.320.3+00:00 R1 RM/6/RMDEBUG:  Destination Address:
10.1.234.1
Nov 24 2011 16:31:48.320.4+00:00 R1 RM/6/RMDEBUG:  Ver# 2, Type: 3 (Link-State
Req)
Nov 24 2011 16:31:48.320.5+00:00 R1 RM/6/RMDEBUG:  Length: 48, Router: 10.0.3.3
Nov 24 2011 16:31:48.320.6+00:00 R1 RM/6/RMDEBUG:  Area: 0.0.0.0, Chksum: c4c2
Nov 24 2011 16:31:48.320.7+00:00 R1 RM/6/RMDEBUG:  AuType: 00
Nov 24 2011 16:31:48.320.8+00:00 R1 RM/6/RMDEBUG:  Key(ascii): 0 0 0 0 0 0 0 0
Nov 24 2011 16:31:48.320.9+00:00 R1 RM/6/RMDEBUG:  # Requesting LSAs: 2
Nov 24 2011 16:31:48.320.10+00:00 R1 RM/6/RMDEBUG:  LSA Type 1
Nov 24 2011 16:31:48.320.11+00:00 R1 RM/6/RMDEBUG:    LS ID: 10.0.1.1
Nov 24 2011 16:31:48.320.12+00:00 R1 RM/6/RMDEBUG:    Adv Rtr: 10.0.1.1
Nov 24 2011 16:31:48.320.13+00:00 R1 RM/6/RMDEBUG:  LSA Type 3
Nov 24 2011 16:31:48.320.14+00:00 R1 RM/6/RMDEBUG:    LS ID: 10.0.1.0
Nov 24 2011 16:31:48.320.15+00:00 R1 RM/6/RMDEBUG:    Adv Rtr: 10.0.1.1
```

附加实验：思考并验证

假设区域2存在一台路由器R6。它计算到达10.0.5.0/24网段的路由信息与R2、R3计算该信息的步骤有什么差异？

类型4的LSA什么时候会出现？

实验中如果将R1和R4都配置成DROther，会有什么隐患？

最终设备配置

```
<R1>display current-configuration
[V200R001C00SPC200]
#
 sysname R1
#
interface GigabitEthernet0/0/0
 ip address 10.1.234.1 255.255.255.0
#
interface LoopBack0
 ip address 10.0.1.1 255.255.255.0
 ospf network-type broadcast
#
ospf 1 router-id 10.0.1.1
 area 0.0.0.0
  network 10.1.234.1 0.0.0.0
 area 0.0.0.2
  network 10.0.1.1 0.0.0.0
#
return

<R2>display current-configuration
[V200R001C00SPC200]
#
 sysname R2
#
interface GigabitEthernet0/0/0
 ip address 10.1.234.2 255.255.255.0
 ospf dr-priority 254
#
interface LoopBack0
 ip address 10.0.2.2 255.255.255.0
 ospf network-type broadcast
#
ospf 1 router-id 10.0.2.2
 area 0.0.0.0
  network 10.1.234.2 0.0.0.0
  network 10.0.2.2 0.0.0.0
```

```
#
return

<R3>display current-configuration
[V200R001C00SPC200]
#
 sysname R3
#
interface Serial3/0/0
 link-protocol ppp
 ip address 10.0.35.3 255.255.255.0
#
interface GigabitEthernet0/0/0
 ip address 10.1.234.3 255.255.255.0
 ospf dr-priority 255
#
interface LoopBack0
 ip address 10.0.3.3 255.255.255.0
 ospf network-type broadcast
#
ospf 1 router-id 10.0.3.3
 area 0.0.0.0
  network 10.1.234.3 0.0.0.0
  network 10.0.3.3 0.0.0.0
 area 0.0.0.1
  network 10.0.35.3 0.0.0.0
#
return

<R4>display current-configuration
[V200R001C00SPC200]
#
 sysname R4
#
interface GigabitEthernet0/0/0
 ip address 10.1.234.4 255.255.255.0
 ospf dr-priority 0
#
interface LoopBack0
 ip address 10.0.4.4 255.255.255.0
 ospf network-type broadcast
#
ospf 1 router-id 10.0.4.4
```

```
 area 0.0.0.0
  network 10.1.234.4 0.0.0.0
  network 10.0.4.4 0.0.0.0
#
return

<R5>display current-configuration
[V200R001C00SPC200]
#
 sysname R5
#
interface Serial1/0/0
 link-protocol ppp
 ip address 10.0.35.5 255.255.255.0
#
interface LoopBack0
 ip address 10.0.5.5 255.255.255.0
#
ospf 1 router-id 10.0.5.5
 import-route direct
 area 0.0.0.1
  network 10.0.35.5 0.0.0.0
#
return
```

实验 2-4 OSPF Stub 区域与 NSSA 区域

学习目的

- 掌握OSPF的Stub区域的配置
- 掌握OSPF的NSSA区域的配置
- 观察LSA Type7的内容
- 理解LSA Type7与Type5之间的转化关系

拓扑图

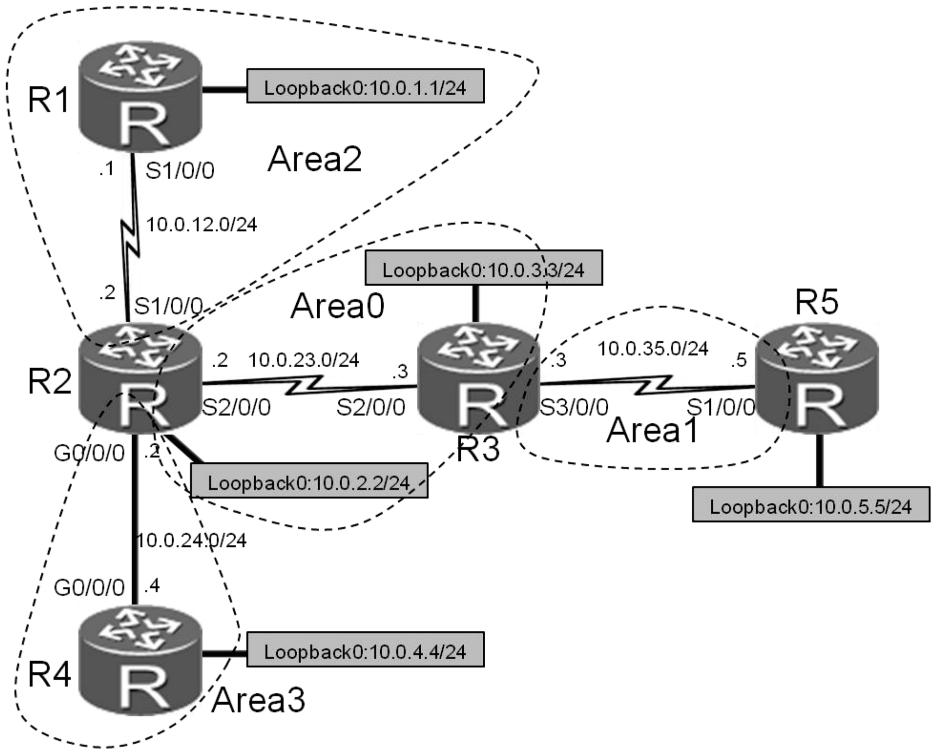


图2-4 OSPF Stub区域与NSSA区域

场景

你是公司的网络管理员。现在公司的网络中有五台AR G3路由器，其中R2、R3和R4在公司总部。R5在公司分部。R3通过专线与公司总部的R3相连。R1在公司的另外一个分部，通过专线与公司总部的R2相连。

网段10.0.23.0/24、10.0.2.0/24、10.0.3.0/24属于区域0。

网段10.0.35.0/24属于区域1，区域1为NSSA区域。R5的Loopback0接口不属于OSPF区域。

网段10.0.24.0/24属于区域3。R4的Loopback0接口连接到Internet，需要配置一条缺省路由。

网段10.0.12.0/24、10.0.1.0/24属于区域2，区域2为Stub区域。

同时为了明确设备的Router-ID，你配置设备使用固定的地址作为Router-ID。

学习任务

步骤一. 基础配置与 IP 编址

给所有路由器配置IP地址和掩码。配置时注意所有的Loopback接口配置掩码均为24位，模拟成一个单独的网段。

```
<R1>system-view
Enter system view, return user view with Ctrl+Z.
[R1]interface Serial 1/0/0
[R1-Serial1/0/0]ip address 10.0.12.1 24
[R1-Serial1/0/0]quit
[R1]interface LoopBack 0
[R1-LoopBack0]ip address 10.0.1.1 24
[R1-LoopBack0]quit

<R2>system-view
Enter system view, return user view with Ctrl+Z.
[R2]interface Serial 1/0/0
[R2-Serial1/0/0]ip address 10.0.12.2 24
[R2-Serial1/0/0]quit
[R2]interface Serial 2/0/0
[R2-Serial2/0/0]ip address 10.0.23.2 24
[R2-Serial2/0/0]quit
[R2]interface GigabitEthernet 0/0/0
```

```
[R2-GigabitEthernet0/0/0]ip address 10.0.24.2 24
[R2-GigabitEthernet0/0/0]quit
[R2]interface LoopBack 0
[R2-LoopBack0]ip address 10.0.2.2 24
[R2-LoopBack0]quit

<R3>system-view
Enter system view, return user view with Ctrl+Z.
[R3]interface Serial 2/0/0
[R3-Serial2/0/0]ip address 10.0.23.3 24
[R3-Serial2/0/0]quit
[R3]interface Serial 3/0/0
[R3-Serial3/0/0]ip address 10.0.35.3 24
[R3-Serial3/0/0]quit
[R3]interface LoopBack 0
[R3-LoopBack0]ip address 10.0.3.3 24
[R3-LoopBack0]quit

<R4>system-view
Enter system view, return user view with Ctrl+Z.
[R4]interface GigabitEthernet 0/0/0
[R4-GigabitEthernet0/0/0]ip address 10.0.24.4 24
[R4-GigabitEthernet0/0/0]quit
[R4]interface LoopBack 0
[R4-LoopBack0]ip address 10.0.4.4 24
[R4-LoopBack0]quit

<R5>system-view
Enter system view, return user view with Ctrl+Z.
[R5]interface Serial 1/0/0
[R5-Serial1/0/0]ip address 10.0.35.5 24
[R5-Serial1/0/0]quit
[R5]interface LoopBack 0
[R5-LoopBack0]ip address 10.0.5.5 24
[R5-LoopBack0]quit
```

测试直连链路的连通性。

```
[R2]ping -c 1 10.0.12.1
  PING 10.0.12.1: 56  data bytes, press CTRL_C to break
    Reply from 10.0.12.1: bytes=56 Sequence=1 ttl=255 time=30 ms

  --- 10.0.12.1 ping statistics ---
    1 packet(s) transmitted
```

```
    1 packet(s) received
    0.00% packet loss
    round-trip min/avg/max = 30/30/30 ms

[R2]ping -c 1 10.0.24.4
  PING 10.0.24.4: 56  data bytes, press CTRL_C to break
    Reply from 10.0.24.4: bytes=56 Sequence=1 ttl=255 time=6 ms

  --- 10.0.24.4 ping statistics ---
    1 packet(s) transmitted
    1 packet(s) received
    0.00% packet loss
    round-trip min/avg/max = 6/6/6 ms

[R2]ping -c 1 10.0.23.3
  PING 10.0.23.3: 56  data bytes, press CTRL_C to break
    Reply from 10.0.23.3: bytes=56 Sequence=1 ttl=255 time=31 ms

  --- 10.0.23.3 ping statistics ---
    1 packet(s) transmitted
    1 packet(s) received
    0.00% packet loss
    round-trip min/avg/max = 31/31/31 ms

[R3]ping -c 1 10.0.35.5
  PING 10.0.35.5: 56  data bytes, press CTRL_C to break
    Reply from 10.0.35.5: bytes=56 Sequence=1 ttl=255 time=38 ms

  --- 10.0.35.5 ping statistics ---
    1 packet(s) transmitted
    1 packet(s) received
    0.00% packet loss
    round-trip min/avg/max = 38/38/38 ms
```

步骤二.　配置多区域 OSPF

在R1上配置Serial 1/0/0及Loopback 0属于区域0，并对所有OSPF区域的Loopback接口，修改其OSPF网络类型为Broadcast类型，以便于OSPF发布Loopback口的真实掩码信息，所有的路由器使用Loopback 0的IP地址作为Router ID。

```
[R1]ospf 1 router-id 10.0.1.1
```

```
[R1-ospf-1]area 2
[R1-ospf-1-area-0.0.0.2]network 10.0.12.1 0.0.0.0
[R1-ospf-1-area-0.0.0.2]network 10.0.1.1 0.0.0.0
[R1-ospf-1-area-0.0.0.2]quit
[R1-ospf-1]quit
[R1]interface LoopBack 0
[R1-LoopBack0]ospf network-type broadcast
[R1-LoopBack0]quit
```

在R2上配置接口Serial 2/0/0及Loopback 0属于区域0，接口Serial 1/0/0属于区域2，接口GigabitEthernet 0/0/0属于区域3。

```
[R2]ospf 1 router-id 10.0.2.2
[R2-ospf-1]area 0
[R2-ospf-1-area-0.0.0.0]network 10.0.23.2 0.0.0.0
[R2-ospf-1-area-0.0.0.0]network 10.0.2.2 0.0.0.0
[R2-ospf-1-area-0.0.0.0]quit
[R2-ospf-1]area 2
[R2-ospf-1-area-0.0.0.2]network 10.0.12.2 0.0.0.0
[R2-ospf-1-area-0.0.0.2]quit
[R2-ospf-1]area 3
[R2-ospf-1-area-0.0.0.3]network 10.0.24.2 0.0.0.0
[R2-ospf-1-area-0.0.0.3]qui
[R2-ospf-1]quit
[R2]int LoopBack 0
[R2-LoopBack0]ospf network-type broadcast
[R2-LoopBack0]quit
```

在R3上配置接口Serial 2/0/0及Loopback 0属于区域0，接口Serial 3/0/0属于区域1。

```
[R3]ospf 1 router-id 10.0.3.3
[R3-ospf-1]area 0
[R3-ospf-1-area-0.0.0.0]network 10.0.23.3 0.0.0.0
[R3-ospf-1-area-0.0.0.0]network 10.0.3.3 0.0.0.0
[R3-ospf-1-area-0.0.0.0]quit
[R3-ospf-1]area 1
[R3-ospf-1-area-0.0.0.1]network 10.0.35.3 0.0.0.0
[R3-ospf-1-area-0.0.0.1]quit
[R3-ospf-1]quit
[R3]interface LoopBack 0
[R3-LoopBack0]ospf network-type broadcast
[R3-LoopBack0]quit
```

在R4上配置接口GigabitEthernet 0/0/0属于区域3，接口Loopback 0不属于任何区域。

```
[R4]ospf 1 router-id 10.0.4.4
[R4-ospf-1]area 3
[R4-ospf-1-area-0.0.0.3]network 10.0.24.4  0.0.0.0
[R4-ospf-1-area-0.0.0.3]quit
[R4-ospf-1]quit
```

在R5上配置接口Serial 1/0/0属于区域1，接口Loopback 0不属于OSPF区域。

```
[R5]ospf 1 router-id 10.0.5.5
[R5-ospf-1]area 1
[R5-ospf-1-area-0.0.0.1]network 10.0.35.5 0.0.0.0
[R5-ospf-1-area-0.0.0.1]quit
[R5-ospf-1]quit
```

配置完成后，在R1上查看路由器的路由表。

```
[R1]display ip routing-table
Route Flags: R - relay, D - download to fib
------------------------------------------------------------------------------
Routing Tables: Public
        Destinations : 16      Routes : 16

Destination/Mask    Proto  Pre  Cost     Flags NextHop        Interface

      10.0.1.0/24   Direct  0    0        D   10.0.1.1        LoopBack0
      10.0.1.1/32   Direct  0    0        D   127.0.0.1       InLoopBack0
    10.0.1.255/32   Direct  0    0        D   127.0.0.1       InLoopBack0
      10.0.2.0/24   OSPF   10   1562      D   10.0.12.2       Serial1/0/0
      10.0.3.0/24   OSPF   10   3124      D   10.0.12.2       Serial1/0/0
     10.0.12.0/24   Direct  0    0        D   10.0.12.1       Serial1/0/0
     10.0.12.1/32   Direct  0    0        D   127.0.0.1       InLoopBack0
     10.0.12.2/32   Direct  0    0        D   10.0.12.2       Serial1/0/0
   10.0.12.255/32   Direct  0    0        D   127.0.0.1       InLoopBack0
     10.0.23.0/24   OSPF   10   3124      D   10.0.12.2       Serial1/0/0
     10.0.24.0/24   OSPF   10   1563      D   10.0.12.2       Serial1/0/0
     10.0.35.0/24   OSPF   10   4686      D   10.0.12.2       Serial1/0/0
     127.0.0.0/8    Direct  0    0        D   127.0.0.1       InLoopBack0
     127.0.0.1/32   Direct  0    0        D   127.0.0.1       InLoopBack0
127.255.255.255/32  Direct  0    0        D   127.0.0.1       InLoopBack0
255.255.255.255/32  Direct  0    0        D   127.0.0.1       InLoopBack0
```

测试全网的连通性。

```
[R1]ping -c 1 10.0.35.5
  PING 10.0.35.5: 56  data bytes, press CTRL_C to break
    Reply from 10.0.35.5: bytes=56 Sequence=1 ttl=253 time=114 ms

  --- 10.0.35.5 ping statistics ---
    1 packet(s) transmitted
    1 packet(s) received
    0.00% packet loss
    round-trip min/avg/max = 114/114/114 ms

[R1]ping -c 1 10.0.3.3
  PING 10.0.3.3: 56  data bytes, press CTRL_C to break
    Reply from 10.0.3.3: bytes=56 Sequence=1 ttl=254 time=74 ms

  --- 10.0.3.3 ping statistics ---
    1 packet(s) transmitted
    1 packet(s) received
    0.00% packet loss
    round-trip min/avg/max = 74/74/74 ms

[R1]ping -c 1 10.0.24.4
  PING 10.0.24.4: 56  data bytes, press CTRL_C to break
    Reply from 10.0.24.4: bytes=56 Sequence=1 ttl=254 time=34 ms

  --- 10.0.24.4 ping statistics ---
    1 packet(s) transmitted
    1 packet(s) received
    0.00% packet loss
    round-trip min/avg/max = 34/34/34 ms
```

步骤三.　配置将外部路由引入到 OSPF

将R5的Loopback0接口网段10.0.5.0/24引入到OSPF区域。使用默认配置进行路由引入。

```
[R5]ospf 1
[R5-ospf-1]import-route direct
```

配置完成后，在R1上查看该路由，并测试网络连通性。

```
[R1]display ip routing-table protocol ospf
```

```
Route Flags: R - relay, D - download to fib
------------------------------------------------------------------------------
Public routing table : OSPF
         Destinations : 7       Routes : 7

OSPF routing table status : <Active>
         Destinations : 7       Routes : 7

Destination/Mask    Proto   Pre  Cost      Flags NextHop         Interface

       10.0.2.0/24  OSPF    10   1562        D   10.0.12.2       Serial1/0/0
       10.0.3.0/24  OSPF    10   3124        D   10.0.12.2       Serial1/0/0
       10.0.5.0/24  O_ASE   150  1           D   10.0.12.2       Serial1/0/0
      10.0.23.0/24  OSPF    10   3124        D   10.0.12.2       Serial1/0/0
      10.0.24.0/24  OSPF    10   1563        D   10.0.12.2       Serial1/0/0
      10.0.35.0/24  OSPF    10   4686        D   10.0.12.2       Serial1/0/0
      10.0.35.3/32  O_ASE   150  1           D   10.0.12.2       Serial1/0/0

OSPF routing table status : <Inactive>
         Destinations : 0       Routes : 0

[R1]ping -c 1 10.0.5.5
  PING 10.0.5.5: 56  data bytes, press CTRL_C to break
    Reply from 10.0.5.5: bytes=56 Sequence=1 ttl=253 time=111 ms

  --- 10.0.5.5 ping statistics ---
    1 packet(s) transmitted
    1 packet(s) received
    0.00% packet loss
    round-trip min/avg/max = 111/111/111 ms
```

在R4上配置缺省路由，下一跳为Loopback0接口。并将该缺省路由引入到OSPF区域，定义为类型1，代价值为20，不使用永久发布。

```
[R4]ip route-static 0.0.0.0 0.0.0.0 LoopBack 0
[R4]ospf 1
[R4-ospf-1]default-route-advertise type 1 cost 20
[R4-ospf-1]quit
```

配置完成后，在R1上查看该缺省路由学习的情况。并测试网络的连通性。

```
[R1]display ip routing-table protocol ospf
Route Flags: R - relay, D - download to fib
------------------------------------------------------------------------------
```

```
Public routing table : OSPF
        Destinations : 7       Routes : 7

OSPF routing table status : <Active>
        Destinations : 7       Routes : 7

Destination/Mask    Proto   Pre  Cost     Flags NextHop        Interface

       0.0.0.0/0   O_ASE    150  1583       D   10.0.12.2       Serial1/0/0
      10.0.2.0/24  OSPF     10   1562       D   10.0.12.2       Serial1/0/0
      10.0.3.0/24  OSPF     10   3124       D   10.0.12.2       Serial1/0/0
      10.0.5.0/24  O_ASE    150  1          D   10.0.12.2       Serial1/0/0
     10.0.23.0/24  OSPF     10   3124       D   10.0.12.2       Serial1/0/0
     10.0.24.0/24  OSPF     10   1563       D   10.0.12.2       Serial1/0/0
     10.0.35.0/24  OSPF     10   4686       D   10.0.12.2       Serial1/0/0
     10.0.35.3/32  O_ASE    150  1          D   10.0.12.2       Serial1/0/0

OSPF routing table status : <Inactive>
        Destinations : 0       Routes : 0

[R1]ping -c 1 10.0.4.4
  PING 10.0.4.4: 56  data bytes, press CTRL_C to break
    Reply from 10.0.4.4: bytes=56 Sequence=1 ttl=254 time=39 ms

  --- 10.0.4.4 ping statistics ---
    1 packet(s) transmitted
    1 packet(s) received
    0.00% packet loss
    round-trip min/avg/max = 39/39/39 ms
```

步骤四. 配置区域 2 为 Stub 区域

在R1上查看路由信息。注意刚才看到的默认路由是外部路由（O_ASE），是通过R4发布的第五类LSA学习到的。

```
 [R1]display ospf lsdb

        OSPF Process 1 with Router ID 10.0.1.1
               Link State Database

                     Area: 0.0.0.2
 Type     LinkState ID    AdvRouter          Age  Len   Sequence   Metric
```

```
Router    10.0.2.2     10.0.2.2         12  48    80000003    1562
Router    10.0.1.1     10.0.1.1         11  60    80000003       0
Sum-Net   10.0.35.0    10.0.2.2         33  28    80000001    3124
Sum-Net   10.0.24.0    10.0.2.2         33  28    80000001       1
Sum-Net   10.0.3.0     10.0.2.2         33  28    80000001    1562
Sum-Net   10.0.2.0     10.0.2.2         33  28    80000001       0
Sum-Net   10.0.23.0    10.0.2.2         34  28    80000001    1562
Sum-Asbr  10.0.4.4     10.0.2.2         34  28    80000001       1
Sum-Asbr  10.0.5.5     10.0.2.2         34  28    80000001    3124


             AS External Database
Type     LinkState ID   AdvRouter         Age  Len   Sequence   Metric
External  0.0.0.0      10.0.4.4        1049  36    80000002      20
External  10.0.5.0     10.0.5.5        1350  36    80000001       1
External  10.0.35.0    10.0.5.5        1350  36    80000001       1
External  10.0.35.3    10.0.5.5        1350  36    80000001       1

[R1]display ospf lsdb ase 0.0.0.0

       OSPF Process 1 with Router ID 10.0.1.1
             Link State Database


 Type       : External
 Ls id      : 0.0.0.0
 Adv rtr    : 10.0.4.4
 Ls age     : 504
 Len        : 36
 Options    :  E
 seq#       : 80000002
 chksum     : 0xa981
 Net mask   : 0.0.0.0
 TOS 0  Metric: 20
 E type     : 1
 Forwarding Address : 0.0.0.0
 Tag        : 1
 Priority  : Low
```

在R1和R2上配置区域2为Stub区域。

```
[R1]ospf 1
[R1-ospf-1]area 2
[R1-ospf-1-area-0.0.0.2]stub
```

```
[R1-ospf-1-area-0.0.0.2]quit
[R1-ospf-1]quit

[R2]ospf 1
[R2-ospf-1]area 2
[R2-ospf-1-area-0.0.0.2]stub
[R2-ospf-1-area-0.0.0.2]quit
[R2-ospf-1]quit
```

配置完成后，在R1上对比之前的路由表，查看路由信息学习情况。这时可以看到，刚才的外部路由消失了，默认路由也变成了内部路由。

```
[R1]display ip routing-table protocol ospf
Route Flags: R - relay, D - download to fib
------------------------------------------------------------------------------
Public routing table : OSPF
         Destinations : 6        Routes : 6

OSPF routing table status : <Active>
         Destinations : 6        Routes : 6

Destination/Mask    Proto  Pre  Cost      Flags NextHop         Interface

        0.0.0.0/0   OSPF   10   1563        D   10.0.12.2       Serial1/0/0
       10.0.2.0/24  OSPF   10   1562        D   10.0.12.2       Serial1/0/0
       10.0.3.0/24  OSPF   10   3124        D   10.0.12.2       Serial1/0/0
      10.0.23.0/24  OSPF   10   3124        D   10.0.12.2       Serial1/0/0
      10.0.24.0/24  OSPF   10   1563        D   10.0.12.2       Serial1/0/0
      10.0.35.0/24  OSPF   10   4686        D   10.0.12.2       Serial1/0/0

OSPF routing table status : <Inactive>
         Destinations : 0        Routes : 0
```

查看R1的LSDB，可以看到描述外部路由的LSA也消失了，默认路由是由一条第三类LSA学习到的。

```
[R1]display ospf lsdb

         OSPF Process 1 with Router ID 10.0.1.1
                 Link State Database

                         Area: 0.0.0.2
 Type      LinkState ID    AdvRouter          Age  Len   Sequence   Metric
 Router    10.0.2.2        10.0.2.2           182  48    80000003    1562
```

```
 Router    10.0.1.1       10.0.1.1          182  60    80000004       0
 Sum-Net   0.0.0.0        10.0.2.2          183  28    80000001       1
 Sum-Net   10.0.35.0      10.0.2.2          183  28    80000001    3124
 Sum-Net   10.0.24.0      10.0.2.2          183  28    80000001       1
 Sum-Net   10.0.3.0       10.0.2.2          183  28    80000001    1562
 Sum-Net   10.0.2.0       10.0.2.2          184  28    80000001       0
 Sum-Net   10.0.23.0      10.0.2.2          184  28    80000001    1562
```

查看这条LSA的详细信息，可以发现这条默认路由是由R2发布的，这就验证了将一个区域配置为Stub区域以后，ABR会阻断第四、五类LSA向该区域发送，并通过三类LSA向该区域内泛洪一条默认路由指向ABR自己。

```
[R1]display ospf lsdb summary 0.0.0.0

       OSPF Process 1 with Router ID 10.0.1.1
                    Area: 0.0.0.2
              Link State Database


  Type       : Sum-Net
  Ls id      : 0.0.0.0
  Adv rtr    : 10.0.2.2
  Ls age     : 114
  Len        : 28
  Options    : None
  seq#       : 80000001
  chksum     : 0x1f31
  Net mask   : 0.0.0.0
  Tos 0  metric: 1
  Priority   : Low
```

在R2上将区域2配置为**no-summary**的完全Stub区域。

```
[R2]ospf 1
[R2-ospf-1]area 2
[R2-ospf-1-area-0.0.0.2]stub no-summary
[R2-ospf-1-area-0.0.0.2]quit
[R2-ospf-1]quit
```

查看R1的路由表，这时发现通过OSPF学习到的路由条目只剩一条默认路由了。

```
[R1]display ip routing-table protocol ospf
Route Flags: R - relay, D - download to fib
----------------------------------------------------------------------------
```

```
Public routing table : OSPF
        Destinations : 1       Routes : 1

OSPF routing table status : <Active>
        Destinations : 1       Routes : 1

Destination/Mask    Proto   Pre  Cost     Flags NextHop        Interface

       0.0.0.0/0    OSPF    10   1563       D   10.0.12.2      Serial1/0/0

OSPF routing table status : <Inactive>
        Destinations : 0       Routes : 0
```

查看R1的LSDB信息，发现除了R1和R2产生的第一类LSA以外，只剩一条由R2发布的三类LSA。

验证了在完全Stub区域中ABR会阻断了第三、四、五类LSA，并生成一条三类LSA，通告一条指向自己的默认路由。

```
[R1]display ospf lsdb

        OSPF Process 1 with Router ID 10.0.1.1
               Link State Database

                     Area: 0.0.0.2
 Type      LinkState ID    AdvRouter          Age  Len   Sequence   Metric
 Router    10.0.2.2        10.0.2.2           167  48    80000004    1562
 Router    10.0.1.1        10.0.1.1           166  60    80000006       0
 Sum-Net   0.0.0.0         10.0.2.2           549  28    80000001       1
```

步骤五.　配置区域 1 为 NSSA 区域

查看R3的路由表，R5发布的10.0.5.0/24是以外部路由的形式出现的。

```
[R3]display ip routing-table protocol ospf
Route Flags: R - relay, D - download to fib
------------------------------------------------------------------------------
Public routing table : OSPF
        Destinations : 7       Routes : 7

OSPF routing table status : <Active>
        Destinations : 6       Routes : 6
```

```
Destination/Mask    Proto   Pre  Cost     Flags NextHop        Interface

       0.0.0.0/0   O_ASE   150  1583        D   10.0.23.2      Serial2/0/0
      10.0.1.0/24  OSPF    10   3124        D   10.0.23.2      Serial2/0/0
      10.0.2.0/24  OSPF    10   1562        D   10.0.23.2      Serial2/0/0
      10.0.5.0/24  O_ASE   150  1           D   10.0.35.5      Serial3/0/0
     10.0.12.0/24  OSPF    10   3124        D   10.0.23.2      Serial2/0/0
     10.0.24.0/24  OSPF    10   1563        D   10.0.23.2      Serial2/0/0

OSPF routing table status : <Inactive>
        Destinations : 1       Routes : 1

Destination/Mask    Proto   Pre  Cost     Flags NextHop        Interface

     10.0.35.3/32  O_ASE   150  1             10.0.35.5      Serial3/0/0
```

在查看R5的路由表和LSDB信息。R5从R4学习到一条外部路由，其余的路由均是内部路由。R5通过第五类LSA向外发布了网络10.0.5.0/24。

```
[R5]display ip routing-table protocol ospf
Route Flags: R - relay, D - download to fib
------------------------------------------------------------------------------
Public routing table : OSPF
        Destinations : 7       Routes : 7

OSPF routing table status : <Active>
        Destinations : 7       Routes : 7

Destination/Mask    Proto   Pre  Cost     Flags NextHop        Interface

       0.0.0.0/0   O_ASE   150  3145      D   10.0.35.3      Serial1/0/0
      10.0.1.0/24  OSPF    10   4686      D   10.0.35.3      Serial1/0/0
      10.0.2.0/24  OSPF    10   3124      D   10.0.35.3      Serial1/0/0
      10.0.3.0/24  OSPF    10   1562      D   10.0.35.3      Serial1/0/0
     10.0.12.0/24  OSPF    10   4686      D   10.0.35.3      Serial1/0/0
     10.0.23.0/24  OSPF    10   3124      D   10.0.35.3      Serial1/0/0
     10.0.24.0/24  OSPF    10   3125      D   10.0.35.3      Serial1/0/0

OSPF routing table status : <Inactive>
        Destinations : 0       Routes : 0

[R5]display ospf lsdb

        OSPF Process 1 with Router ID 10.0.5.5
```

```
             Link State Database

                    Area: 0.0.0.1
 Type      LinkState ID    AdvRouter          Age  Len   Sequence   Metric
 Router    10.0.5.5        10.0.5.5           882  48    80000004    1562
 Router    10.0.3.3        10.0.3.3          1309  48    80000003    1562
 Sum-Net   10.0.24.0       10.0.3.3            65  28    80000003    1563
 Sum-Net   10.0.12.0       10.0.3.3           819  28    80000001    3124
 Sum-Net   10.0.3.0        10.0.3.3            65  28    80000003       0
 Sum-Net   10.0.2.0        10.0.3.3            65  28    80000003    1562
 Sum-Net   10.0.1.0        10.0.3.3           812  28    80000001    3124
 Sum-Net   10.0.23.0       10.0.3.3            65  28    80000003    1562
 Sum-Asbr  10.0.4.4        10.0.3.3           602  28    80000002    1563


             AS External Database
 Type      LinkState ID    AdvRouter          Age  Len   Sequence   Metric
 External  10.0.5.0        10.0.5.5           882  36    80000002       1
 External  10.0.35.0       10.0.5.5           883  36    80000002       1
 External  10.0.35.3       10.0.5.5           883  36    80000002       1
 External  0.0.0.0         10.0.4.4           586  36    80000003      20
```

配置R3和R5的区域1为NSSA区域。

```
[R3]ospf
[R3-ospf-1]area 1
[R3-ospf-1-area-0.0.0.1]nssa

[R5]ospf
[R5-ospf-1]area 1
[R5-ospf-1-area-0.0.0.1]nssa
```

待邻居关系重新建立后，在R3上查看路由表。

```
[R3]display ip routing-table protocol ospf
Route Flags: R - relay, D - download to fib
------------------------------------------------------------------------------
Public routing table : OSPF
        Destinations : 7       Routes : 7

OSPF routing table status : <Active>
        Destinations : 6       Routes : 6

Destination/Mask    Proto   Pre  Cost      Flags NextHop         Interface
```

```
     0.0.0.0/0   O_ASE    150  1583       D  10.0.23.2      Serial2/0/0
    10.0.1.0/24  OSPF     10   3124       D  10.0.23.2      Serial2/0/0
    10.0.2.0/24  OSPF     10   1562       D  10.0.23.2      Serial2/0/0
    10.0.5.0/24  O_NSSA   150  1          D  10.0.35.5      Serial3/0/0
   10.0.12.0/24  OSPF     10   3124       D  10.0.23.2      Serial2/0/0
   10.0.24.0/24  OSPF     10   1563       D  10.0.23.2      Serial2/0/0

OSPF routing table status : <Inactive>
        Destinations : 1       Routes : 1

Destination/Mask    Proto   Pre  Cost     Flags NextHop        Interface

     10.0.35.3/32  O_NSSA  150  1            10.0.35.5      Serial3/0/0
```

此时，R5通告的外部路由是以O_NSSA的形式出现在路由表里的。

再查看R5的路由表。

```
[R5]display ip routing-table protocol ospf
Route Flags: R - relay, D - download to fib
------------------------------------------------------------------------------
Public routing table : OSPF
        Destinations : 7       Routes : 7

OSPF routing table status : <Active>
        Destinations : 7       Routes : 7

Destination/Mask    Proto   Pre  Cost     Flags NextHop        Interface

     0.0.0.0/0   O_NSSA  150  1          D  10.0.35.3      Serial1/0/0
    10.0.1.0/24  OSPF    10   4686       D  10.0.35.3      Serial1/0/0
    10.0.2.0/24  OSPF    10   3124       D  10.0.35.3      Serial1/0/0
    10.0.3.0/24  OSPF    10   1562       D  10.0.35.3      Serial1/0/0
   10.0.12.0/24  OSPF    10   4686       D  10.0.35.3      Serial1/0/0
   10.0.23.0/24  OSPF    10   3124       D  10.0.35.3      Serial1/0/0
   10.0.24.0/24  OSPF    10   3125       D  10.0.35.3      Serial1/0/0

OSPF routing table status : <Inactive>
        Destinations : 0       Routes : 0
```

刚才默认路由是以外部路由（O_ASE）的形式出现的，现在该默认路由变成了NSSA区域的外部路由（O_NSSA）。

查看R5的LSDB。

```
[R5]display ospf lsdb

       OSPF Process 1 with Router ID 10.0.5.5
              Link State Database

                    Area: 0.0.0.1
 Type      LinkState ID     AdvRouter         Age  Len   Sequence   Metric
 Router    10.0.5.5         10.0.5.5          811  48    80000007    1562
 Router    10.0.3.3         10.0.3.3          811  48    80000007    1562
 Sum-Net   10.0.24.0        10.0.3.3          929  28    80000005    1563
 Sum-Net   10.0.12.0        10.0.3.3          929  28    80000005    3124
 Sum-Net   10.0.3.0         10.0.3.3          929  28    80000005       0
 Sum-Net   10.0.2.0         10.0.3.3          929  28    80000005    1562
 Sum-Net   10.0.1.0         10.0.3.3          930  28    80000005    3124
 Sum-Net   10.0.23.0        10.0.3.3          930  28    80000005    1562
 NSSA      10.0.5.0         10.0.5.5          819  36    80000005       1
 NSSA      10.0.35.0        10.0.5.5          819  36    80000006       1
 NSSA      10.0.35.3        10.0.5.5          819  36    80000005       1
 NSSA      0.0.0.0          10.0.3.3          930  36    80000005       1
```

发现，刚才的第五类LSA都消失了，外部路由以第七类LSA的形式向外通告。

查看默认路由的明细信息。

```
[R5]display ospf lsdb nssa 0.0.0.0

       OSPF Process 1 with Router ID 10.0.5.5
                    Area: 0.0.0.1
              Link State Database


  Type       : NSSA
  Ls id      : 0.0.0.0
  Adv rtr    : 10.0.3.3
  Ls age     : 1149
  Len        : 36
  Options    : None
  seq#       : 80000005
  chksum     : 0x7745
  Net mask   : 0.0.0.0
  TOS 0  Metric: 1
  E type     : 2
  Forwarding Address : 0.0.0.0
  Tag        : 1
```

```
 Priority  : Low
```

刚才R5上的默认路由是R4通告给它的，而现在这条默认路由的通告者是R3。

从上面的结果我们可知，NSSA区域阻断了外部的第四、五类LSA进入，并且ABR会以第七类LSA的形式，向区域内通告一条默认路由。本区域的外部路由会以第七类LSA的形式，由ASBR向NSSA区域内通告。

NSSA和Stub区域的根本区别是，NSSA区域允许引入外部路由，而Stub区域不可以。

步骤六.　观察 NSSA 给 OSPF 带来的变化

使用**display ospf brief**命令查看R3目前所处的OSPF角色，可以看到，在Border Router这个字段有三个值：AREA　AS　NSSA。AREA表示该路由器是一台ABR，AS表示该路由器是一台ASBR，NSSA表示该路由器至少有一个接口位于NSSA区域。

```
[R3]display ospf brief

       OSPF Process 1 with Router ID 10.0.3.3
              OSPF Protocol Information

 RouterID: 10.0.3.3        Border Router:  AREA  AS  NSSA
 Multi-VPN-Instance is not enabled
 Global DS-TE Mode: Non-Standard IETF Mode
 Graceful-restart capability: disabled
 Helper support capability  : not configured
 Spf-schedule-interval: max 10000ms, start 500ms, hold 1000ms
 Default ASE parameters: Metric: 1 Tag: 1 Type: 2
 Route Preference: 10
 ASE Route Preference: 150
 SPF Computation Count: 15
 RFC 1583 Compatible
 Retransmission limitation is disabled
 Area Count: 2   Nssa Area Count: 1
 ExChange/Loading Neighbors: 0

Area: 0.0.0.0
 Authtype: None   Area flag: Normal
 SPF scheduled Count: 7
 ExChange/Loading Neighbors: 0

 Interface: 10.0.3.3 (LoopBack0)
```

```
Cost: 0      State: P-2-P    Type: P2P      MTU: 1500
Timers: Hello 10 , Dead 40 , Poll  120 , Retransmit 5 , Transmit Delay 1

 Interface: 10.0.23.3 (Serial2/0/0) --> 10.0.23.2
Cost: 1562    State: P-2-P    Type: P2P      MTU: 1500
Timers: Hello 10 , Dead 40 , Poll  120 , Retransmit 5 , Transmit Delay 1

Area: 0.0.0.1
Authtype: None   Area flag:   NSSA
SPF scheduled Count: 8
ExChange/Loading Neighbors: 0
NSSA Translator State: Elected

 Interface: 10.0.35.3 (Serial3/0/0) --> 10.0.35.5
Cost: 1562    State: P-2-P    Type: P2P      MTU: 1500
Timers: Hello 10 , Dead 40 , Poll  120 , Retransmit 5 , Transmit Delay 1
```

在NSSA区域中，由于不允许第五类LSA存在，所以ASBR是以第七类LSA的形式，向区域内通告外部路由的。但第七类LSA仅允许在NSSA区域内泛洪，NSSA区域的ABR收到这个第七类的LSA后，会将该第七类LSA转换成第五类LSA，然后向其他普通区域发布。

接下来我们在R3上观察7类LSA与5类LSA的转换过程。以10.0.5.0/24为例观察路由信息的传递。对于第七类LSA，Ls id描述了目的网段，Net mask描述了目的网段对应的掩码。Options字段为NP表示该LSA可以被ABR转化成一条第五类LSA，如果Options字段显示此LSA不可以被转换成第五类LSA，则Forwarding Address可以被设置成0.0.0.0；如果Options字段显示此LSA可以被转换成第五类LSA，则Forwarding Address不能被设置0.0.0.0。

在这里，所引入外部路由的下一跳不在OSPF路由域内，Forwarding Address设置为该ASBR上某个OSPF路由域内的Stub网段的接口IP地址。这里使用的地址为R5的Serial 1/0/0的接口地址。

```
[R3]display ospf lsdb nssa 10.0.5.0

         OSPF Process 1 with Router ID 10.0.3.3
                         Area: 0.0.0.0
                 Link State Database

                         Area: 0.0.0.1
                 Link State Database


  Type      : NSSA
```

```
  Ls id     : 10.0.5.0
  Adv rtr   : 10.0.5.5
  Ls age    : 836
  Len       : 36
  Options   :  NP
  seq#      : 80000001
  chksum    : 0xb0c2
  Net mask  : 255.255.255.0
  TOS 0  Metric: 1
  E type    : 2
  Forwarding Address : 10.0.35.5
  Tag       : 1
  Priority  : Low
```

查看R3生成的用于描述10.0.5.0/24的第五类LSA。

```
[R3]display ospf lsdb ase 10.0.5.0

       OSPF Process 1 with Router ID 10.0.3.3
              Link State Database


  Type      : External
  Ls id     : 10.0.5.0
  Adv rtr   : 10.0.3.3
  Ls age    : 882
  Len       : 36
  Options   :  E
  seq#      : 80000001
  chksum    : 0x413e
  Net mask  : 255.255.255.0
  TOS 0  Metric: 1
  E type    : 2
  Forwarding Address : 10.0.35.5
  Tag       : 1
  Priority  : Low
```

Ls id、Network Mask和Forwarding Address这几个字段的值直接从原来第七类LSA中拷贝。这样，10.0.5.0/24这个网段就被通告到其他区域了。

附加实验: 思考并验证

NSSA区域类型适合用在哪些场景？

分析为什么R3路由器被定义为ASBR？

最终设备配置

```
<R1>display current-configuration
[V200R001C00SPC200]
#
 sysname R1
#
interface Serial1/0/0
 link-protocol ppp
 ip address 10.0.12.1 255.255.255.0
#
interface LoopBack0
 ip address 10.0.1.1 255.255.255.0
 ospf network-type broadcast
#
ospf 1 router-id 10.0.1.1
 area 0.0.0.2
  network 10.0.12.1 0.0.0.0
  network 10.0.1.1 0.0.0.0
  stub
#
return
```

```
<R2>display current-configuration
[V200R001C00SPC200]
#
 sysname R2
#
interface Serial1/0/0
 link-protocol ppp
 ip address 10.0.12.2 255.255.255.0
#
interface Serial2/0/0
 link-protocol ppp
 ip address 10.0.23.2 255.255.255.0
#
interface GigabitEthernet0/0/0
 ip address 10.0.24.2 255.255.255.0
#
interface LoopBack0
 ip address 10.0.2.2 255.255.255.0
```

```
 ospf network-type broadcast
#
ospf 1 router-id 10.0.2.2
 area 0.0.0.0
  network 10.0.23.2 0.0.0.0
  network 10.0.2.2 0.0.0.0
 area 0.0.0.2
  network 10.0.12.2 0.0.0.0
  stub no-summary
 area 0.0.0.3
  network 10.0.24.2 0.0.0.0
#
return
```

```
<R3>display current-configuration
[V200R001C00SPC200]
#
 sysname R3
#
interface Serial2/0/0
 link-protocol ppp
 ip address 10.0.23.3 255.255.255.0
#
interface Serial3/0/0
 link-protocol ppp
 ip address 10.0.35.3 255.255.255.0
#
interface LoopBack0
 ip address 10.0.3.3 255.255.255.0
 ospf network-type broadcast
#
ospf 1 router-id 10.0.3.3
 area 0.0.0.0
  network 10.0.23.3 0.0.0.0
  network 10.0.3.3 0.0.0.0
 area 0.0.0.1
  network 10.0.35.3 0.0.0.0
  nssa
#
return
```

```
<R4>display current-configuration
[V200R001C00SPC200]
```

```
#
 sysname R4
#
interface GigabitEthernet0/0/0
 ip address 10.0.24.4 255.255.255.0
#
interface NULL0
#
interface LoopBack0
 ip address 10.0.4.4 255.255.255.0
 ospf network-type broadcast
#
ospf 1 router-id 10.0.4.4
 default-route-advertise cost 20 type 1
 area 0.0.0.3
  network 10.0.24.4 0.0.0.0
#
 ip route-static 0.0.0.0 0.0.0.0 LoopBack0
#
return

<R5>display current-configuration
[V200R001C00SPC200]
#
 sysname R5
#
interface Serial1/0/0
 link-protocol ppp
 ip address 10.0.35.5 255.255.255.0
#
interface LoopBack0
 ip address 10.0.5.5 255.255.255.0
#
ospf 1 router-id 10.0.5.5
 import-route direct
 area 0.0.0.1
  network 10.0.35.5 0.0.0.0
  nssa
#
return
```

实验 2-5 OSPF 虚电路和区域路由过滤

学习目的

- 掌握使用OSPF虚电路来连接不连续的区域0的配置方法
- 掌握使用OSPF虚电路将非骨干区域连接到区域0的配置方法
- 掌握区域之间进行路由过滤和路由控制的方法

拓扑图

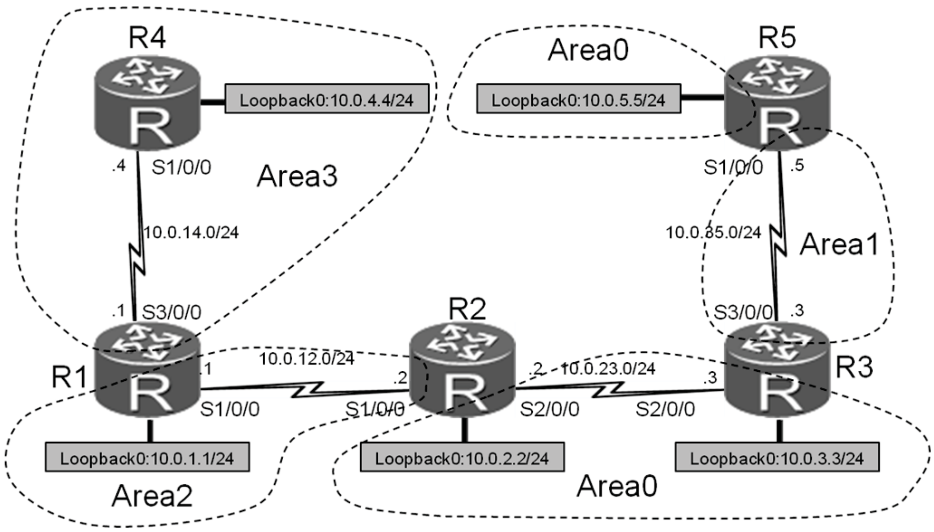


图2-5 OSPF虚电路和区域路由过滤

场景

你是公司的网络管理员。公司最近收购了两家小公司，他们的路由器是R4和R5。为了尽快合并网络，你决定先不去重新规划网络，而是使用虚电路实现网络互联。

网络直接相连后，你发现存在不连续的区域0，另外区域3与区域0没有直接连接。所以你决定在R1和R2之间建立虚电路，实现区域3与区域0的直接连接。另外在R3和R5之间建立虚电路，将不连续的区域0连接到一块。

同时为了明确设备的Router-ID，你配置设备使用固定的地址作为Router-ID。

学习任务

步骤一. 基础配置与 IP 编址

给所有路由器配置IP地址和掩码。配置时注意所有的Loopback接口配置掩码均为24位，模拟成一个单独的网段。

```
<R1>system-view
Enter system view, return user view with Ctrl+Z.
[R1]interface Serial 3/0/0
[R1-Serial3/0/0]ip address 10.0.14.1 24
[R1-Serial3/0/0]interface Serial 1/0/0
[R1-Serial1/0/0]ip address 10.0.12.1 24
[R1-Serial1/0/0]interface LoopBack 0
[R1-LoopBack0]ip address 10.0.1.1 24

<R2>system-view
Enter system view, return user view with Ctrl+Z.
[R2]interface Serial 1/0/0
[R2-Serial1/0/0]ip address 10.0.12.2 24
[R2-Serial1/0/0]interface Serial 2/0/0
[R2-Serial2/0/0]ip address 10.0.23.2 24
[R2-Serial2/0/0]interface LoopBack 0
[R2-LoopBack0]ip address 10.0.2.2 24

<R3>system-view
Enter system view, return user view with Ctrl+Z.
[R3]interface Serial 2/0/0
[R3-Serial2/0/0]ip address 10.0.23.3 24
[R3-Serial2/0/0]interface Serial 3/0/0
[R3-Serial3/0/0]ip address 10.0.35.3 24
[R3-Serial3/0/0]interface LoopBack 0
[R3-LoopBack0]ip address 10.0.3.3 24

<R4>system-view
Enter system view, return user view with Ctrl+Z.
[R4]interface Serial 1/0/0
[R4-Serial1/0/0]ip address 10.0.14.4 24
[R4-Serial1/0/0]interface LoopBack 0
```

```
[R4-LoopBack0]ip address 10.0.4.4 24

<R5>system-view
Enter system view, return user view with Ctrl+Z.
[R5]interface Serial 1/0/0
[R5-Serial1/0/0]ip address 10.0.35.5 24
[R5-Serial1/0/0]interface LoopBack 0
[R5-LoopBack0]ip address 10.0.5.5 24
```

配置完成后，测试直连链路的连通性。

```
[R1]ping -c 1 10.0.14.4
  PING 10.0.14.4: 56  data bytes, press CTRL_C to break
    Reply from 10.0.14.4: bytes=56 Sequence=1 ttl=255 time=39 ms

  --- 10.0.14.4 ping statistics ---
    1 packet(s) transmitted
    1 packet(s) received
    0.00% packet loss
    round-trip min/avg/max = 39/39/39 ms

[R1]ping -c 1 10.0.12.2
  PING 10.0.12.2: 56  data bytes, press CTRL_C to break
    Reply from 10.0.12.2: bytes=56 Sequence=1 ttl=255 time=29 ms

  --- 10.0.12.2 ping statistics ---
    1 packet(s) transmitted
    1 packet(s) received
    0.00% packet loss
    round-trip min/avg/max = 29/29/29 ms

[R3]ping -c 1 10.0.23.2
  PING 10.0.23.2: 56  data bytes, press CTRL_C to break
    Reply from 10.0.23.2: bytes=56 Sequence=1 ttl=255 time=45 ms

  --- 10.0.23.2 ping statistics ---
    1 packet(s) transmitted
    1 packet(s) received
    0.00% packet loss
    round-trip min/avg/max = 45/45/45 ms

[R3]ping -c 1 10.0.35.5
  PING 10.0.35.5: 56  data bytes, press CTRL_C to break
    Reply from 10.0.35.5: bytes=56 Sequence=1 ttl=255 time=32 ms
```

```
--- 10.0.35.5 ping statistics ---
  1 packet(s) transmitted
  1 packet(s) received
  0.00% packet loss
  round-trip min/avg/max = 32/32/32 ms
```

步骤二. 配置多区域 OSPF

在R1上配置Serial 1/0/0及Loopback 0属于区域2，Serial 3/0/0属于区域3。并对所有OSPF区域的Loopback接口，修改其OSPF网络类型为Broadcast类型，以便于OSPF发布Loopback口的真实掩码信息。所有的路由器使用Loopback 0的IP地址作为Router ID。

```
[R1]ospf 1 router-id 10.0.1.1
[R1-ospf-1]area 2
[R1-ospf-1-area-0.0.0.2]network 10.0.12.1 0.0.0.0
[R1-ospf-1-area-0.0.0.2]network 10.0.1.1 0.0.0.0
[R1-ospf-1-area-0.0.0.2]area 3
[R1-ospf-1-area-0.0.0.3]network 10.0.14.1 0.0.0.0
[R1-ospf-1-area-0.0.0.3]interface LoopBack 0
[R1-LoopBack0]ospf network-type broadcast
```

在R2上配置Serial 2/0/0及Loopback 0属于区域0，Serial 1/0/0属于区域2。

```
[R2]ospf 1 router-id 10.0.2.2
[R2-ospf-1]area 2
[R2-ospf-1-area-0.0.0.2]network 10.0.12.2 0.0.0.0
[R2-ospf-1-area-0.0.0.2]area 0
[R2-ospf-1-area-0.0.0.0]network 10.0.23.2 0.0.0.0
[R2-ospf-1-area-0.0.0.0]network 10.0.2.2 0.0.0.0
[R2-ospf-1-area-0.0.0.0]int LoopBack 0
[R2-LoopBack0]ospf network-type broadcast
```

在R3上配置Serial 2/0/0及Loopback 0属于区域0，Serial 3/0/0属于区域1。

```
[R3]ospf 1 router-id 10.0.3.3
[R3-ospf-1]area 0
[R3-ospf-1-area-0.0.0.0]network 10.0.23.3 0.0.0.0
[R3-ospf-1-area-0.0.0.0]network 10.0.3.3 0.0.0.0
[R3-ospf-1-area-0.0.0.0]area 1
[R3-ospf-1-area-0.0.0.1]network 10.0.35.3 0.0.0.0
```

```
[R3-ospf-1-area-0.0.0.1]interface LoopBack 0
[R3-LoopBack0]ospf network-type broadcast
```

在R4上配置Serial 1/0/0及Loopback 0属于区域3

```
[R4]ospf 1 router-id 10.0.4.4
[R4-ospf-1]area 3
[R4-ospf-1-area-0.0.0.3]network 10.0.14.4 0.0.0.0
[R4-ospf-1-area-0.0.0.3]network 10.0.4.4 0.0.0.0
[R4-ospf-1-area-0.0.0.3]interface LoopBack 0
[R4-LoopBack0]ospf network-type broadcast
```

在R5上配置Serial 1/0/0属于区域1，Loopback 0属于区域0。

```
[R5]ospf 1 router-id 10.0.5.5
[R5-ospf-1]area 0
[R5-ospf-1-area-0.0.0.0]network 10.0.5.5 0.0.0.0
[R5-ospf-1-area-0.0.0.0]area 1
[R5-ospf-1-area-0.0.0.1]network 10.0.35.5 0.0.0.0
[R5-ospf-1-area-0.0.0.1]interface LoopBack 0
[R5-LoopBack0]ospf network-type broadcast
```

步骤三.　查看每个路由器的路由表

查看R4的路由表，R4虽然与R1建立了邻接关系，没有学习到任何OSPF路由。

```
[R4]display ip routing-table protocol ospf
[R4]display ospf peer

        OSPF Process 1 with Router ID 10.0.4.4
               Neighbors

 Area 0.0.0.3 interface 10.0.14.4(Serial1/0/0)'s neighbors
 Router ID: 10.0.1.1        Address: 10.0.14.1
   State: Full  Mode:Nbr is  Slave  Priority: 1
   DR: None   BDR: None   MTU: 0
   Dead timer due in 39  sec
   Retrans timer interval: 4
   Neighbor is up for 00:21:33
   Authentication Sequence: [ 0 ]
```

再查看R4的LSDB发现仅存在第一类LSA，也就是说R1没有将其他区域的路由通告进区域3。

```
[R4]display ospf lsdb

        OSPF Process 1 with Router ID 10.0.4.4
               Link State Database

                      Area: 0.0.0.3
 Type      LinkState ID    AdvRouter          Age  Len   Sequence   Metric
 Router    10.0.4.4        10.0.4.4           571  60    80000005      0
 Router    10.0.1.1        10.0.1.1           616  48    80000003    1562
```

查看R1的路由表，缺失了10.0.5.0/24。至于缺少这条路由的原因，我们分析完R3的LSDB就明白了。

```
[R1]display ip routing-table protocol ospf
Route Flags: R - relay, D - download to fib
------------------------------------------------------------------------------
Public routing table : OSPF
        Destinations : 5       Routes : 5

OSPF routing table status : <Active>
        Destinations : 5       Routes : 5

Destination/Mask   Proto   Pre  Cost     Flags NextHop        Interface


      10.0.2.0/24  OSPF    10   1562       D   10.0.12.2      Serial1/0/0
      10.0.3.0/24  OSPF    10   3124       D   10.0.12.2      Serial1/0/0
      10.0.4.0/24  OSPF    10   1562       D   10.0.14.4      Serial3/0/0
     10.0.23.0/24  OSPF    10   3124       D   10.0.12.2      Serial1/0/0
     10.0.35.0/24  OSPF    10   4686       D   10.0.12.2      Serial1/0/0

OSPF routing table status : <Inactive>
        Destinations : 0       Routes : 0
```

下面我们先来看一下R1的LSDB。为了避免区域间的环路，OSPF规定不允许直接在两个非骨干区域之间发布路由信息。从LSDB的角度来看，可以发现，ABR不会转发从非骨干区域收到的第三类LSA。

在R1上我们可以看到，在区域2的LSDB中有4条区域间路由，该路由是从R2（10.0.2.2）上学习到的，R1并没有将这些LSA转发到区域3里，所以R4学习不到非本区域的路由。

ABR也不会将从非骨干区域中学习到的路由转发给另一个非骨干区域，这里R1从R4这里学习到的路由不会以第三类LSA的形式通告进区域2，所以R2、R3、R5均学习不到区域3内的路由。

```
[R1]display ospf lsdb

       OSPF Process 1 with Router ID 10.0.1.1
             Link State Database

                   Area: 0.0.0.2
 Type      LinkState ID    AdvRouter          Age  Len   Sequence   Metric
 Router    10.0.2.2        10.0.2.2          1251  48    80000023    1562
 Router    10.0.1.1        10.0.1.1          1266  60    80000024       0
 Sum-Net   10.0.35.0       10.0.2.2          1178  28    8000001B    3124
 Sum-Net   10.0.3.0        10.0.2.2          1178  28    8000001B    1562
 Sum-Net   10.0.2.0        10.0.2.2          1228  28    80000021       0
 Sum-Net   10.0.23.0       10.0.2.2          1189  28    8000001B    1562

                   Area: 0.0.0.3
 Type      LinkState ID    AdvRouter          Age  Len   Sequence   Metric
 Router    10.0.4.4        10.0.4.4           855  60    80000024       0
 Router    10.0.1.1        10.0.1.1           898  48    80000022    1562
```

查看R2的路由表，在R2的路由表中缺失了到达网络10.0.4.0/24、10.0.5.0/24、10.0.14.0/24的三条路由。

```
[R2]display ip routing-table protocol ospf
Route Flags: R - relay, D - download to fib
------------------------------------------------------------------------------
Public routing table : OSPF
       Destinations : 3       Routes : 3

OSPF routing table status : <Active>
       Destinations : 3       Routes : 3

Destination/Mask   Proto   Pre  Cost     Flags NextHop        Interface


     10.0.1.0/24  OSPF    10   1562       D   10.0.12.1      Serial1/0/0
     10.0.3.0/24  OSPF    10   1562       D   10.0.23.3      Serial2/0/0
    10.0.35.0/24  OSPF    10   3124       D   10.0.23.3      Serial2/0/0

OSPF routing table status : <Inactive>
       Destinations : 0       Routes : 0
```

查看R2的LSDB，可以发现R1没有将区域3的路由通告给R2。

R2上会缺失到达网络10.0.4.0/24、10.0.14.0/24的路由。

在区域0中，R3也没有将10.0.5.0网络的路由通告给R2。

```
[R2]display ospf lsdb

         OSPF Process 1 with Router ID 10.0.2.2
                 Link State Database

                        Area: 0.0.0.0
 Type      LinkState ID    AdvRouter          Age  Len   Sequence   Metric
 Router    10.0.3.3        10.0.3.3           973  60    80000027       0
 Router    10.0.2.2        10.0.2.2           972  60    80000028       0
 Sum-Net   10.0.35.0       10.0.3.3           984  28    8000001D    1562
 Sum-Net   10.0.12.0       10.0.2.2          1035  28    80000022    1562
 Sum-Net   10.0.1.0        10.0.2.2          1035  28    80000022    1562

                        Area: 0.0.0.2
 Type      LinkState ID    AdvRouter          Age  Len   Sequence   Metric
 Router    10.0.2.2        10.0.2.2          1046  48    80000024    1562
 Router    10.0.1.1        10.0.1.1          1063  60    80000025       0
 Sum-Net   10.0.35.0       10.0.2.2           973  28    8000001C    3124
 Sum-Net   10.0.3.0        10.0.2.2           973  28    8000001C    1562
 Sum-Net   10.0.2.0        10.0.2.2          1023  28    80000022       0
 Sum-Net   10.0.23.0       10.0.2.2           984  28    8000001C    1562
```

查看R3的路由表，缺失了到达网络10.0.4.0/24、10.0.5.0/24、10.0.14.0/24的路由。

```
[R3]display ip routing-table protocol ospf
Route Flags: R - relay, D - download to fib
------------------------------------------------------------------------------
Public routing table : OSPF
         Destinations : 3        Routes : 3

OSPF routing table status : <Active>
         Destinations : 3        Routes : 3

Destination/Mask    Proto   Pre  Cost      Flags NextHop         Interface

       10.0.1.0/24  OSPF    10   3124        D   10.0.23.2       Serial2/0/0
       10.0.2.0/24  OSPF    10   1562        D   10.0.23.2       Serial2/0/0
      10.0.12.0/24  OSPF    10   3124        D   10.0.23.2       Serial2/0/0

OSPF routing table status : <Inactive>
         Destinations : 0        Routes : 0
```

查看R3的LSDB，我们可以发现，R3从区域1中收到了R5发来的第三类10.0.5.0。根据前面的原则，从非骨干区域收到的第三类LSA不会被转发。

R3没有将这条LSA再次发送到区域0中，这也正是R1和R2中没有10.0.5.0/24这条路由的原因。

```
[R3]display ospf lsdb

	 OSPF Process 1 with Router ID 10.0.3.3
		 Link State Database

		         Area: 0.0.0.0
 Type      LinkState ID    AdvRouter          Age  Len   Sequence   Metric
 Router    10.0.3.3        10.0.3.3           111  60    80000028      0
 Router    10.0.2.2        10.0.2.2           112  60    80000029      0
 Sum-Net   10.0.35.0       10.0.3.3           122  28    8000001E    1562
 Sum-Net   10.0.12.0       10.0.2.2           175  28    80000023    1562
 Sum-Net   10.0.1.0        10.0.2.2           175  28    80000023    1562

		         Area: 0.0.0.1
 Type      LinkState ID    AdvRouter          Age  Len   Sequence   Metric
 Router    10.0.5.5        10.0.5.5           117  48    8000001E    1562
 Router    10.0.3.3        10.0.3.3           117  48    80000020    1562
 Sum-Net   10.0.12.0       10.0.3.3           107  28    8000001D    3124
 Sum-Net   10.0.3.0        10.0.3.3           128  28    8000001D       0
 Sum-Net   10.0.2.0        10.0.3.3           107  28    8000001D    1562
 Sum-Net   10.0.1.0        10.0.3.3           108  28    8000001D    3124
 Sum-Net   10.0.5.0        10.0.5.5           128  28    8000001D       0
 Sum-Net   10.0.23.0       10.0.3.3           124  28    8000001D    1562
```

在这里我们注意到，R3的LSDB中已经有了R5发来的用于描述10.0.5.0/24的第三类LSA，但在R3的路由表上并没有出现这条路由。

查看R5的路由表。

```
[R5]display ip routing-table protocol ospf
Route Flags: R - relay, D - download to fib
------------------------------------------------------------------------------
Public routing table : OSPF
         Destinations : 5       Routes : 5

OSPF routing table status : <Active>
         Destinations : 5       Routes : 5

Destination/Mask    Proto   Pre  Cost      Flags NextHop        Interface
```

```
     10.0.1.0/24  OSPF    10   4686       D   10.0.35.3      Serial1/0/0
     10.0.2.0/24  OSPF    10   3124       D   10.0.35.3      Serial1/0/0
     10.0.3.0/24  OSPF    10   1562       D   10.0.35.3      Serial1/0/0
    10.0.12.0/24  OSPF    10   4686       D   10.0.35.3      Serial1/0/0
    10.0.23.0/24  OSPF    10   3124       D   10.0.35.3      Serial1/0/0

OSPF routing table status : <Inactive>
        Destinations : 0       Routes : 0

 [R5]display ospf lsdb

        OSPF Process 1 with Router ID 10.0.5.5
               Link State Database

                     Area: 0.0.0.0
 Type      LinkState ID    AdvRouter          Age  Len   Sequence   Metric
 Router    10.0.5.5       10.0.5.5           820  36   80000002      0
 Sum-Net   10.0.35.0      10.0.5.5           861  28   80000001    1562

                     Area: 0.0.0.1
 Type      LinkState ID    AdvRouter          Age  Len   Sequence   Metric
 Router    10.0.5.5       10.0.5.5          1096  48   80000003    1562
 Router    10.0.3.3       10.0.3.3          1097  48   80000002    1562
 Sum-Net   10.0.12.0      10.0.3.3          1129  28   80000001    3124
 Sum-Net   10.0.3.0       10.0.3.3          1129  28   80000001      0
 Sum-Net   10.0.2.0       10.0.3.3          1129  28   80000001    1562
 Sum-Net   10.0.1.0       10.0.3.3          1129  28   80000001    3124
 Sum-Net   10.0.5.0       10.0.5.5           861  28   80000001      0
 Sum-Net   10.0.23.0      10.0.3.3          1129  28   80000001    1562
```

R5缺失了到达网络10.0.4.0/24、10.0.14.0/24的路由。

同时可以看到，R5上存在到达R3 Loopback 0的路由。

分析原因可知，R3存在连接到区域0的物理接口，即可以与区域0中其他的路由器交互路由信息，这时在R3上不会将非骨干区域发来的第三类LSA学习到的路由加到路由表里。R5虽然有接口在区域0中，但该接口为Loopback接口，Loopback接口在OSPF进行路由计算时为StubNet的链路类型。

查看R3的产生的类型一的LSA。

```
[R3]display ospf lsdb router 10.0.3.3

        OSPF Process 1 with Router ID 10.0.3.3
```

```
                    Area: 0.0.0.0
              Link State Database


  Type      : Router
  Ls id     : 10.0.3.3
  Adv rtr   : 10.0.3.3
  Ls age    : 732
  Len       : 60
  Options   :  ABR  E
  seq#      : 80000158
  chksum    : 0xde39
  Link count: 3
   * Link ID: 10.0.3.3
     Data   : 255.255.255.255
     Link Type: StubNet
     Metric : 0
     Priority : Medium
   * Link ID: 10.0.2.2
     Data   : 10.0.23.3
     Link Type: P-2-P
     Metric : 1562
   * Link ID: 10.0.23.0
     Data   : 255.255.255.0
     Link Type: StubNet
     Metric : 1562
     Priority : Low
```

从上面的输出中可以看到，R3与R2相连的链路的类型为P-2-P。类型为P-2-P、TransNet和Virtual类型的链路，路由器均认为该接口与其他路由器会交互路由信息。对于存在这三类链路连接到骨干区域的路由器不会将非骨干区域发来的第三类LSA加到路由表中。

```
[R5]display ospf lsdb router 10.0.5.5

       OSPF Process 1 with Router ID 10.0.5.5
                    Area: 0.0.0.0
              Link State Database


  Type      : Router
  Ls id     : 10.0.5.5
  Adv rtr   : 10.0.5.5
  Ls age    : 583
```

```
Len      : 36
Options   :  ABR  E
seq#     : 80000040
chksum    : 0x6d69
Link count: 1
 * Link ID: 10.0.5.5
   Data   : 255.255.255.255
   Link Type: StubNet
   Metric : 0
   Priority : Medium
```

在R5上，骨干区域中仅有一个Loopback 0，在描述这个接口的LSA中，链路的类型是StubNet，即末节网络，表示该接口不会再连接其他路由器，这时，路由器就会采用从非骨干区域发来的第三类LSA。

步骤四. 将不连续的区域 0 连在一块

在R3和R5上配置虚电路，注意在配置虚电路的时候在**vlink-peer**中配置的是对端ABR的Router ID。

```
[R3]ospf 1
[R3-ospf-1]area 1
[R3-ospf-1-area-0.0.0.1]vlink-peer 10.0.5.5

[R5]ospf
[R5-ospf-1]area 1
[R5-ospf-1-area-0.0.0.1]vlink-peer 10.0.3.3
```

然后检查虚电路邻居的状态是否为Full。

```
[R3]display ospf vlink

       OSPF Process 1 with Router ID 10.0.3.3
              Virtual Links

 Virtual-link Neighbor-id  -> 10.0.5.5, Neighbor-State: Full

 Interface: 10.0.35.3 (Serial3/0/0)
 Cost: 1562  State: P-2-P  Type: Virtual
 Transit Area: 0.0.0.1
 Timers: Hello 10 , Dead 40 , Retransmit 5 , Transmit Delay 1
 GR State: Normal
```

观察路由信息发生的变化。

```
[R3]display ip routing-table protocol ospf
Route Flags: R - relay, D - download to fib
----------------------------------------------------------------------------
Public routing table : OSPF
        Destinations : 4       Routes : 4

OSPF routing table status : <Active>
        Destinations : 4       Routes : 4

Destination/Mask    Proto  Pre  Cost      Flags NextHop        Interface

      10.0.1.0/24  OSPF    10   3124        D   10.0.23.2      Serial2/0/0
      10.0.2.0/24  OSPF    10   1562        D   10.0.23.2      Serial2/0/0
      10.0.5.0/24  OSPF    10   1562        D   10.0.35.5      Serial3/0/0
     10.0.12.0/24  OSPF    10   3124        D   10.0.23.2      Serial2/0/0

OSPF routing table status : <Inactive>
        Destinations : 0       Routes : 0
```

在R3上查看路由表发现已经学习到了10.0.5.0/24这条路由。

测试网络的连通性，R3可以与R5的Loopback 0连接的网段通讯。

```
[R3]ping -c 1 10.0.5.5
  PING 10.0.5.5: 56  data bytes, press CTRL_C to break
    Reply from 10.0.5.5: bytes=56 Sequence=1 ttl=255 time=34 ms

  --- 10.0.5.5 ping statistics ---
    1 packet(s) transmitted
    1 packet(s) received
    0.00% packet loss
    round-trip min/avg/max = 34/34/34 ms
```

查看R3的LSDB。

```
<R3>dis ospf lsdb

        OSPF Process 1 with Router ID 10.0.3.3
               Link State Database

                     Area: 0.0.0.0
 Type      LinkState ID    AdvRouter          Age  Len   Sequence   Metric
 Router     10.0.5.5       10.0.5.5          1098  48    80000005        0
```

```
Router    10.0.3.3       10.0.3.3         1096  72    80000008       0
Router    10.0.2.2       10.0.2.2          920  60    80000006       0
Sum-Net   10.0.35.0      10.0.3.3          830  28    80000002    1562
Sum-Net   10.0.35.0      10.0.5.5          565  28    80000002    1562
Sum-Net   10.0.12.0      10.0.2.2         1124  28    80000002    1562
Sum-Net   10.0.1.0       10.0.2.2         1110  28    80000002    1562

                    Area: 0.0.0.1
Type      LinkState ID   AdvRouter          Age  Len   Sequence   Metric
Router    10.0.5.5       10.0.5.5         1098  48    80000004    1562
Router    10.0.3.3       10.0.3.3         1096  48    80000003    1562
Sum-Net   10.0.12.0      10.0.3.3          830  28    80000002    3124
Sum-Net   10.0.3.0       10.0.3.3          831  28    80000002       0
Sum-Net   10.0.2.0       10.0.3.3          831  28    80000002    1562
Sum-Net   10.0.1.0       10.0.3.3          831  28    80000002    3124
Sum-Net   10.0.5.0       10.0.5.5          566  28    80000002       0
Sum-Net   10.0.23.0      10.0.3.3          831  28    80000002    1562
```

看到在R3上共收到了2条来自R5的第一类LSA。第一条是在区域0中收到的，虚电路属于区域0，所以该LSA实际上是通过虚电路学习到的。另一条第一类LSA是在区域1中学习到的，这条LSA刚才没建虚电路的时候就有。路由表中的10.0.5.0/24路由是通过区域0学习到的LSA计算出的。

查看R3的LSDB中关于10.0.5.5这条第一类LSA的详细信息。

```
[R3]display ospf lsdb router 10.0.5.5

       OSPF Process 1 with Router ID 10.0.3.3
                    Area: 0.0.0.0
             Link State Database

 Type      : Router
 Ls id     : 10.0.5.5
 Adv rtr   : 10.0.5.5
 Ls age    : 621
 Len       : 48
 Options   :  ABR  E
 seq#      : 80000005
 chksum    : 0x1291
 Link count: 2
  * Link ID: 10.0.5.0
    Data   : 255.255.255.0
    Link Type: StubNet
    Metric : 0
```

```
     Priority : Low
   * Link ID: 10.0.3.3
     Data   : 10.0.35.5
     Link Type: Virtual
     Metric : 1562
                     Area: 0.0.0.1
             Link State Database


  Type      : Router
  Ls id     : 10.0.5.5
  Adv rtr    : 10.0.5.5
  Ls age    : 621
  Len       : 48
  Options    :  ABR  VIRTUAL  E
  seq#      : 80000004
  chksum    : 0x3530
  Link count: 2
   * Link ID: 10.0.3.3
     Data   : 10.0.35.5
     Link Type: P-2-P
     Metric : 1562
   * Link ID: 10.0.35.0
     Data   : 255.255.255.0
     Link Type: StubNet
     Metric : 1562
     Priority : Low
```

可以看到这条LSA中描述了网络10.0.5.0/24，所以在R3上就有了这条路由。而从区域1中学习到的这条第一类LSA仅描述了R3和R5的互联网段。

查看R5的LSDB。

```
[R5]display ospf lsdb

       OSPF Process 1 with Router ID 10.0.5.5
             Link State Database

                     Area: 0.0.0.0
 Type      LinkState ID    AdvRouter          Age  Len   Sequence   Metric
 Router    10.0.5.5        10.0.5.5           577   48    80000005      0
 Router    10.0.3.3        10.0.3.3           577   72    80000008      0
 Router    10.0.2.2        10.0.2.2           401   60    80000006      0
 Sum-Net   10.0.35.0       10.0.5.5            45   28    80000002    1562
```

```
Sum-Net   10.0.35.0      10.0.3.3          312  28    80000002    1562
Sum-Net   10.0.12.0      10.0.2.2          606  28    80000002    1562
Sum-Net   10.0.1.0       10.0.2.2          593  28    80000002    1562

                   Area: 0.0.0.1
Type      LinkState ID   AdvRouter          Age  Len   Sequence   Metric
Router    10.0.5.5       10.0.5.5          578  48    80000004    1562
Router    10.0.3.3       10.0.3.3          578  48    80000003    1562
Sum-Net   10.0.12.0      10.0.3.3          313  28    80000002    3124
Sum-Net   10.0.3.0       10.0.3.3          313  28    80000002       0
Sum-Net   10.0.2.0       10.0.3.3          313  28    80000002    1562
Sum-Net   10.0.1.0       10.0.3.3          313  28    80000002    3124
Sum-Net   10.0.5.0       10.0.5.5           46  28    80000002       0
Sum-Net   10.0.23.0      10.0.3.3          313  28    80000002    1562
```

可以发现和R3的LSDB是一样的。建立的虚电路以后，R3和R5均有接口属于区域0了，所以LSDB是同步的。

步骤五. 区域 3 通过虚电路连接到区域 0

在R1和R2上配置虚电路。

```
[R1]ospf 1
[R1-ospf-1]area 2
[R1-ospf-1-area-0.0.0.2]vlink-peer 10.0.2.2
[R1-ospf-1-area-0.0.0.2]quit
[R1-ospf-1]quit

[R2]ospf
[R2-ospf-1]area 2
[R2-ospf-1-area-0.0.0.2]vlink-peer 10.0.1.1
[R2-ospf-1-area-0.0.0.2]quit
[R2-ospf-1]quit
```

查看R4的OSPF路由表。

```
[R4]display ip routing-table protocol ospf
Route Flags: R - relay, D - download to fib
------------------------------------------------------------------------------
Public routing table : OSPF
        Destinations : 7       Routes : 7
```

```
OSPF routing table status : <Active>
        Destinations : 7       Routes : 7

Destination/Mask   Proto   Pre  Cost     Flags NextHop        Interface

      10.0.1.0/24  OSPF    10   1562       D   10.0.14.1      Serial1/0/0
      10.0.2.0/24  OSPF    10   3124       D   10.0.14.1      Serial1/0/0
      10.0.3.0/24  OSPF    10   4686       D   10.0.14.1      Serial1/0/0
      10.0.5.0/24  OSPF    10   6248       D   10.0.14.1      Serial1/0/0
     10.0.12.0/24  OSPF    10   3124       D   10.0.14.1      Serial1/0/0
     10.0.23.0/24  OSPF    10   4686       D   10.0.14.1      Serial1/0/0
     10.0.35.0/24  OSPF    10   6248       D   10.0.14.1      Serial1/0/0

OSPF routing table status : <Inactive>
        Destinations : 0       Routes : 0
```

发现该路由器已拥有了全网路由。

测试网络的连通性。

```
[R4]ping -c 1 10.0.5.5
  PING 10.0.5.5: 56  data bytes, press CTRL_C to break
    Reply from 10.0.5.5: bytes=56 Sequence=1 ttl=252 time=132 ms

  --- 10.0.5.5 ping statistics ---
    1 packet(s) transmitted
    1 packet(s) received
    0.00% packet loss
    round-trip min/avg/max = 132/132/132 ms
```

查看R1的LSDB。

```
[R1]display ospf lsdb

        OSPF Process 1 with Router ID 10.0.1.1
               Link State Database

                      Area: 0.0.0.0
 Type      LinkState ID    AdvRouter          Age  Len   Sequence   Metric
 Router    10.0.5.5       10.0.5.5           419  48    80000006      0
 Router    10.0.3.3       10.0.3.3           418  72    80000009      0
 Router    10.0.2.2       10.0.2.2           232  72    8000000A      0
 Router    10.0.1.1       10.0.1.1           233  36    80000001   1562
 Sum-Net   10.0.35.0      10.0.3.3           151  28    80000003   1562
 Sum-Net   10.0.35.0      10.0.5.5          1687  28    80000002   1562
```

```
Sum-Net   10.0.14.0      10.0.1.1          291  28    80000001    1562
Sum-Net   10.0.12.0      10.0.1.1          291  28    80000001    1562
Sum-Net   10.0.12.0      10.0.2.2          444  28    80000003    1562
Sum-Net   10.0.1.0       10.0.1.1          291  28    80000001       0
Sum-Net   10.0.1.0       10.0.2.2          430  28    80000003    1562
Sum-Net   10.0.4.0       10.0.1.1          291  28    80000001    1562

                    Area: 0.0.0.2
Type      LinkState ID   AdvRouter          Age  Len   Sequence   Metric
Router    10.0.2.2       10.0.2.2          235  48    80000005    1562
Router    10.0.1.1       10.0.1.1          234  60    80000009       0
Sum-Net   10.0.35.0      10.0.2.2          151  28    80000003    3124
Sum-Net   10.0.14.0      10.0.1.1          291  28    80000001    1562
Sum-Net   10.0.3.0       10.0.2.2          234  28    80000003    1562
Sum-Net   10.0.2.0       10.0.2.2          443  28    80000003       0
Sum-Net   10.0.5.0       10.0.2.2          402  28    80000002    3124
Sum-Net   10.0.4.0       10.0.1.1          292  28    80000001    1562
Sum-Net   10.0.23.0      10.0.2.2          286  28    80000003    1562

                    Area: 0.0.0.3
Type      LinkState ID   AdvRouter          Age  Len   Sequence   Metric
Router    10.0.4.4       10.0.4.4         1193  60    80000005       0
Router    10.0.1.1       10.0.1.1          292  48    80000004    1562
Sum-Net   10.0.35.0      10.0.1.1          292  28    80000001    4686
Sum-Net   10.0.12.0      10.0.1.1          294  28    80000001    1562
Sum-Net   10.0.3.0       10.0.1.1          294  28    80000001    3124
Sum-Net   10.0.2.0       10.0.1.1          294  28    80000001    1562
Sum-Net   10.0.1.0       10.0.1.1          294  28    80000001       0
Sum-Net   10.0.5.0       10.0.1.1          294  28    80000001    4686
Sum-Net   10.0.23.0      10.0.1.1          294  28    80000001    3124
```

由于创建了虚电路，R1中有了区域0的LSA，这样区域0和区域3就可以直接交互路由信息了。R1把区域0中的路由信息以第三类LSA的形式通告进了区域3。

查看R4的LSDB。

```
[R4]display ospf lsdb

       OSPF Process 1 with Router ID 10.0.4.4
              Link State Database

                    Area: 0.0.0.3
Type      LinkState ID   AdvRouter          Age  Len   Sequence   Metric
Router    10.0.4.4       10.0.4.4         1303  60    80000005       0
```

```
Router    10.0.1.1       10.0.1.1         404  48    80000004    1562
Sum-Net   10.0.35.0      10.0.1.1         404  28    80000001    4686
Sum-Net   10.0.12.0      10.0.1.1         404  28    80000001    1562
Sum-Net   10.0.3.0       10.0.1.1         404  28    80000001    3124
Sum-Net   10.0.2.0       10.0.1.1         404  28    80000001    1562
Sum-Net   10.0.1.0       10.0.1.1         405  28    80000001       0
Sum-Net   10.0.5.0       10.0.1.1         405  28    80000001    4686
Sum-Net   10.0.23.0      10.0.1.1         405  28    80000001    3124
```

可以看到该路由器学习到了R1发布的第三类LSA。

R4有其他区域的路由。

步骤六.　配置区域之间的路由过滤

控制10.0.4.0/24网段的路由信息的发布。使R1可以学到该路由，但R2、R3、R5学不到这条路由。

设置一个访问控制列表。

```
[R1]acl number 2000
[R1-acl-basic-2000]rule deny source 10.0.4.0 0.0.0.255
[R1-acl-basic-2000]rule permit
```

R1配置针对类型3的LSA的过滤，配置在区域3向其他区域发送更新时进行过滤。

```
[R1]ospf 1
[R1-ospf-1]area 3
[R1-ospf-1-area-0.0.0.3]filter 2000 export
```

在R2上查看路由信息过滤的情况。

```
[R2]dis ip routing-table protocol ospf
Route Flags: R - relay, D - download to fib
------------------------------------------------------------------------------
Public routing table : OSPF
        Destinations : 5       Routes : 5

OSPF routing table status : <Active>
        Destinations : 5       Routes : 5

Destination/Mask    Proto   Pre  Cost     Flags NextHop        Interface


      10.0.1.0/24  OSPF    10   1562       D   10.0.12.1      Serial1/0/0
```

```
      10.0.3.0/24  OSPF   10   1562       D   10.0.23.3      Serial2/0/0
      10.0.5.0/24  OSPF   10   3124       D   10.0.23.3      Serial2/0/0
     10.0.14.0/24  OSPF   10   3124       D   10.0.12.1      Serial1/0/0
     10.0.35.0/24  OSPF   10   3124       D   10.0.23.3      Serial2/0/0

OSPF routing table status : <Inactive>
        Destinations : 0       Routes : 0
```

R2已经学习不到路由10.0.4.0/24了。

此时R1的路由表中仍然有该条目。因为R1和R4是同一个区域的，R4通过第一类LSA把该路由通告给R1。

```
[R1]display ip routing-table protocol ospf
Route Flags: R - relay, D - download to fib
------------------------------------------------------------------------------
Public routing table : OSPF
        Destinations : 6       Routes : 6

OSPF routing table status : <Active>
        Destinations : 6       Routes : 6

Destination/Mask    Proto  Pre  Cost     Flags NextHop        Interface

      10.0.2.0/24  OSPF   10   1562       D   10.0.12.2      Serial1/0/0
      10.0.3.0/24  OSPF   10   3124       D   10.0.12.2      Serial1/0/0
      10.0.4.0/24  OSPF   10   1562       D   10.0.14.4      Serial3/0/0
      10.0.5.0/24  OSPF   10   4686       D   10.0.12.2      Serial1/0/0
     10.0.23.0/24  OSPF   10   3124       D   10.0.12.2      Serial1/0/0
     10.0.35.0/24  OSPF   10   4686       D   10.0.12.2      Serial1/0/0

OSPF routing table status : <Inactive>
        Destinations : 0       Routes : 0
```

附加实验：思考并验证

OSPF协议中为什么区域0必须连续？从当前的OSPF设计的角度来看，是否可以对类型1和类型2的LSA进行过滤？

最终设备配置

```
<R1>display current-configuration
```

```
[V200R001C00SPC200]
#
 sysname R1
#
acl number 2000
 rule 5 deny source 10.0.4.0 0.0.0.255
 rule 10 permit
#
interface Serial1/0/0
 link-protocol ppp
 ip address 10.0.12.1 255.255.255.0
#
interface Serial3/0/0
 link-protocol ppp
 ip address 10.0.14.1 255.255.255.0
#
interface LoopBack0
 ip address 10.0.1.1 255.255.255.0
 ospf network-type broadcast
#
ospf 1 router-id 10.0.1.1
 area 0.0.0.0
 area 0.0.0.2
  network 10.0.1.1 0.0.0.0
  network 10.0.12.1 0.0.0.0
  vlink-peer 10.0.2.2
 area 0.0.0.3
  filter 2000 export
  network 10.0.14.1 0.0.0.0
#
return

<R2>display current-configuration
[V200R001C00SPC200]
#
 sysname R2
#
interface Serial1/0/0
 link-protocol ppp
 ip address 10.0.12.2 255.255.255.0
#
interface Serial2/0/0
 link-protocol ppp
```

```
 ip address 10.0.23.2 255.255.255.0
#
interface LoopBack0
 ip address 10.0.2.2 255.255.255.0
 ospf network-type broadcast
#
ospf 1 router-id 10.0.2.2
 area 0.0.0.0
  network 10.0.23.2 0.0.0.0
  network 10.0.2.2 0.0.0.0
 area 0.0.0.2
  network 10.0.12.2 0.0.0.0
  vlink-peer 10.0.1.1
#
return

<R3>display current-configuration
[V200R001C00SPC200]
#
 sysname R3
#
interface Serial2/0/0
 link-protocol ppp
 ip address 10.0.23.3 255.255.255.0
#
interface Serial3/0/0
 link-protocol ppp
 ip address 10.0.35.3 255.255.255.0
#
interface LoopBack0
 ip address 10.0.3.3 255.255.255.0
 ospf network-type broadcast
#
ospf 1 router-id 10.0.3.3
 area 0.0.0.0
  network 10.0.3.3 0.0.0.0
  network 10.0.23.3 0.0.0.0
 area 0.0.0.1
  network 10.0.35.3 0.0.0.0
  vlink-peer 10.0.5.5
#
return
```

```
<R4>display current-configuration
[V200R001C00SPC200]
#
 sysname R4
#
interface Serial1/0/0
 link-protocol ppp
 ip address 10.0.14.4 255.255.255.0
#
interface LoopBack0
 ip address 10.0.4.4 255.255.255.0
 ospf network-type broadcast
#
ospf 1 router-id 10.0.4.4
 area 0.0.0.3
  network 10.0.14.4 0.0.0.0
  network 10.0.4.4 0.0.0.0
#
return
```

```
<R5>display current-configuration
[V200R001C00SPC200]
#
 sysname R5
#
interface Serial1/0/0
 link-protocol ppp
 ip address 10.0.35.5 255.255.255.0
#
interface LoopBack0
 ip address 10.0.5.5 255.255.255.0
 ospf network-type broadcast
#
ospf 1 router-id 10.0.5.5
 area 0.0.0.0
  network 10.0.5.5 0.0.0.0
 area 0.0.0.1
  network 10.0.35.5 0.0.0.0
  vlink-peer 10.0.3.3
#
return
```

实验 2-6 OSPF 故障排除

学习目的

- 掌握对单区域OSPF中区域号码不匹配进行故障排除的方法
- 掌握对单区域OSPF中掩码不匹配进行故障排除的方法
- 掌握对单区域OSPF中Hello时间不匹配进行故障排除的方法
- 掌握对单区域OSPF中Router-id冲突进行故障排除的方法
- 掌握OSPF认证相关的故障排除方法
- 掌握OSPF汇总相关的故障排除方法
- 掌握虚电路相关的故障排除方法

拓扑图

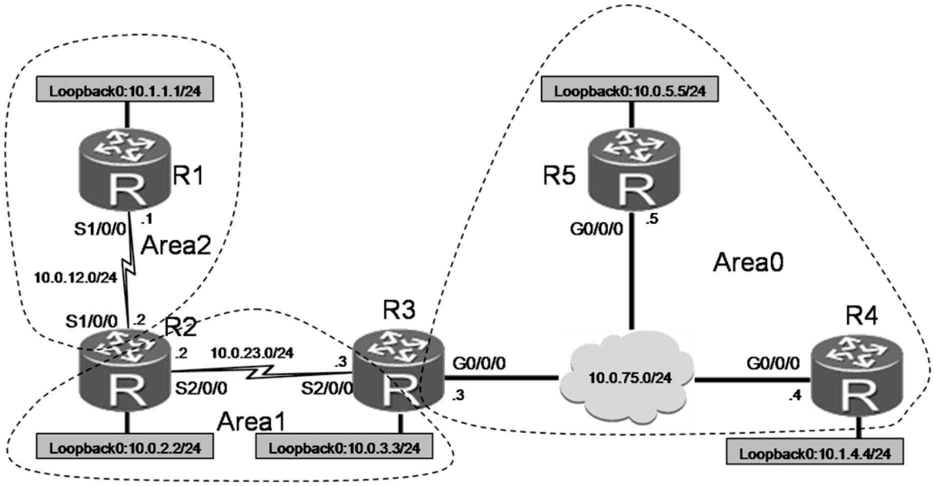


图2-6 OSPF 故障排除

场景

你是公司的网络管理员。公司的网络采用了OSPF协议作为路由协议。OSPF协议功能强大，但是相应的配置也较为复杂。并且在网络规划中，你使用了OSPF的各种特性，同时也使用了虚链路。在实施过程中，你碰到很多的网络通讯问题。不过庆幸的是，通过使用故障排除的思想和方法，你成功的找到了各种错误，并实现了网络的恢复。

学习任务

步骤一.　基础配置与 IP 编址

给所有路由器配置IP地址和掩码。配置时注意所有的Loopback接口配置掩码均为24位，模拟成一个单独的网段。

```
<R1>system-view
Enter system view, return user view with Ctrl+Z.
[R1]int Serial 1/0/0
[R1-Serial1/0/0]ip address 10.0.12.1 24
[R1-Serial1/0/0]interface LoopBack 0
[R1-LoopBack0]ip address 10.1.1.1 24

<R2>system-view
Enter system view, return user view with Ctrl+Z.
[R2]int Serial 1/0/0
[R2-Serial1/0/0]ip address 10.0.12.2 24
[R2-Serial1/0/0]interface Serial 2/0/0
[R2-Serial2/0/0]ip address 10.0.23.2 24
[R2-Serial2/0/0]interface LoopBack 0
[R2-LoopBack0]ip address 10.0.2.2 24
```

为模拟相应的错误，R3的G0/0/0接口配置IP地址为10.0.75.3/25，其余接口地址按照拓扑图中的标识进行配置。

```
<R3>system-view
Enter system view, return user view with Ctrl+Z.
[R3]interface Serial 2/0/0
[R3-Serial2/0/0]ip address 10.0.23.3 24
[R3-Serial2/0/0]interface GigabitEthernet 0/0/0
[R3-GigabitEthernet0/0/0]ip address 10.0.75.3 25
[R3-GigabitEthernet0/0/0]interface LoopBack 0
[R3-LoopBack0]ip address 10.0.3.3 24
```

```
<R4>system-view
Enter system view, return user view with Ctrl+Z.
[R4]interface GigabitEthernet 0/0/0
[R4-GigabitEthernet0/0/0]ip address 10.0.75.4 24
[R4-GigabitEthernet0/0/0]interface LoopBack 0
[R4-LoopBack0]ip address 10.1.4.4 24

<R5>system-view
Enter system view, return user view with Ctrl+Z.
[R5]interface GigabitEthernet 0/0/0
[R5-GigabitEthernet0/0/0]ip address 10.0.75.5 24
[R5-GigabitEthernet0/0/0]interface LoopBack 0
[R5-LoopBack0]ip address 10.0.5.5 24
```

配置完成后，测试直连链路的连通性。

```
[R3]ping -c 1 10.0.75.4
  PING 10.0.75.4: 56  data bytes, press CTRL_C to break
    Reply from 10.0.75.4: bytes=56 Sequence=1 ttl=255 time=5 ms

  --- 10.0.75.4 ping statistics ---
    1 packet(s) transmitted
    1 packet(s) received
    0.00% packet loss
    round-trip min/avg/max = 5/5/5 ms

[R3]ping -c 1 10.0.75.5
  PING 10.0.75.5: 56  data bytes, press CTRL_C to break
    Reply from 10.0.75.5: bytes=56 Sequence=1 ttl=255 time=5 ms

  --- 10.0.75.5 ping statistics ---
    1 packet(s) transmitted
    1 packet(s) received
    0.00% packet loss
    round-trip min/avg/max = 5/5/5 ms

[R3]ping -c 1 10.0.23.2
  PING 10.0.23.2: 56  data bytes, press CTRL_C to break
    Reply from 10.0.23.2: bytes=56 Sequence=1 ttl=255 time=41 ms

  --- 10.0.23.2 ping statistics ---
    1 packet(s) transmitted
    1 packet(s) received
```

```
    0.00% packet loss
    round-trip min/avg/max = 41/41/41 ms

[R1]ping -c 1 10.0.12.2
  PING 10.0.12.2: 56  data bytes, press CTRL_C to break
    Reply from 10.0.12.2: bytes=56 Sequence=1 ttl=255 time=37 ms

  --- 10.0.12.2 ping statistics ---
    1 packet(s) transmitted
    1 packet(s) received
    0.00% packet loss
    round-trip min/avg/max = 37/37/37 ms
```

步骤二. 配置多区域 OSPF

配置R1的接口Serial 1/0/0和Loopback 0属于区域2 ,使用接口Loopback 0的地址作为Router ID。注意对所有OSPF区域的Loopback接口，修改其OSPF网络类型为Broadcast类型，以便于OSPF发布Loopback口的真实掩码信息。

```
[R1]ospf 1 router-id 10.1.1.1
[R1-ospf-1]area 2
[R1-ospf-1-area-0.0.0.2]network 10.0.12.1 0.0.0.0
[R1-ospf-1-area-0.0.0.2]network 10.1.1.1 0.0.0.0
[R1-ospf-1-area-0.0.0.2]interface LoopBack 0
[R1-LoopBack0]ospf network-type broadcast
```

在R2上配置接口Serial 2/0/0及Loopback 0属于区域1，接口Serial 1/0/0属于区域2，在启用OSPF时没有静态指定Router ID。

```
[R2]ospf 1
[R2-ospf-1]area 1
[R2-ospf-1-area-0.0.0.1]network 10.0.23.2 0.0.0.0
[R2-ospf-1-area-0.0.0.1]network 10.0.2.2 0.0.0.0
[R2-ospf-1-area-0.0.0.1]area 2
[R2-ospf-1-area-0.0.0.2]network 10.0.12.2 0.0.0.0
[R2-ospf-1-area-0.0.0.2]int LoopBack 0
[R2-LoopBack0]ospf network-type broadcast
```

在R3上配置接口Serial 2/0/0及Loopback 0属于区域1，接口GigabitEthernet 0/0/0属于区域0。

```
[R3]ospf 1 router-id 10.0.3.3
[R3-ospf-1]area 1
```

```
[R3-ospf-1-area-0.0.0.1]network 10.0.23.3 0.0.0.0
[R3-ospf-1-area-0.0.0.1]network 10.0.3.3 0.0.0.0
[R3-ospf-1-area-0.0.0.1]area 0
[R3-ospf-1-area-0.0.0.0]network 10.0.75.3 0.0.0.0
[R3-ospf-1-area-0.0.0.0]interface LoopBack 0
[R3-LoopBack0]ospf network-type broadcast
```

在R4上配置接口GigabitEthernet 0/0/0属于区域1，接口Loopback 0不属于任何区域。在配置OSPF进程时使用**ospf 1 router-id**指定R4的Router ID为10.0.5.5。

```
[R4]ospf 1 router-id 10.0.5.5
[R4-ospf-1]area 1
[R4-ospf-1-area-0.0.0.1]network 10.0.75.4 0.0.0.0
```

在R5上配置接口GigabitEthernet 0/0/0和Loopback 0属于区域0。

```
[R5]ospf 1 router-id 10.0.5.5
[R5-ospf-1]area 0
[R5-ospf-1-area-0.0.0.0]network 10.0.75.5 0.0.0.0
[R5-ospf-1-area-0.0.0.0]network 10.0.5.5 0.0.0.0
[R5-ospf-1-area-0.0.0.0]interface LoopBack 0
[R5-LoopBack0]ospf network-type broadcast
```

步骤三. 在区域内排除 OSPF 故障

查看R4邻居列表，发现R4没有与其他路由器建立邻居关系。

```
[R4]display ospf peer

       OSPF Process 1 with Router ID 10.0.5.5
```

在R3、R4、R5上分别运行**display ospf error**查看OSPF发生的错误。

```
[R3]display ospf error

       OSPF Process 1 with Router ID 10.0.3.3
              OSPF error statistics

General packet errors:
 0    : IP: received my own packet     2450  : Bad packet
 0    : Bad version                    0     : Bad checksum
 1032 : Bad area id                    0     : Drop on unnumbered interface
```

```
 0     : Bad virtual link              0     : Bad authentication type
 0     : Bad authentication key        0     : Packet too small
 0     : Packet size > ip length       0     : Transmit error
 2     : Interface down                0     : Unknown neighbor

HELLO packet errors:
 2450  : Netmask mismatch              0     : Hello timer mismatch
 0     : Dead timer mismatch           0     : Extern option mismatch
 0     : Router id confusion           0     : Virtual neighbor unknown
 0     : NBMA neighbor unknown         0     : Invalid Source Address

[R4]display ospf error

       OSPF Process 1 with Router ID 10.0.5.5
              OSPF error statistics

General packet errors:
 0     : IP: received my own packet 1354  : Bad packet
 0     : Bad version                   0     : Bad checksum
 0     : Bad area id                   0     : Drop on unnumbered interface
 1032 : Bad virtual link               0     : Bad authentication type
 0     : Bad authentication key        0     : Packet too small
 0     : Packet size > ip length       0     : Transmit error
 3     : Interface down                0     : Unknown neighbor

HELLO packet errors:
 1354  : Netmask mismatch              0     : Hello timer mismatch
 0     : Dead timer mismatch            0     : Extern option mismatch
 1155  : Router id confusion           0     : Virtual neighbor unknown
 0     : NBMA neighbor unknown         0     : Invalid Source Address

[R5]display ospf error

       OSPF Process 1 with Router ID 10.0.5.5
              OSPF error statistics

General packet errors:
 0     : IP: received my own packet    1216  : Bad packet
 0     : Bad version                   0     : Bad checksum
 0     : Bad area id                   0     : Drop on unnumbered interface
 0     : Bad virtual link              0     : Bad authentication type
 0     : Bad authentication key        0     : Packet too small
 0     : Packet size > ip length       0     : Transmit error
```

```
 3     : Interface down                 0     : Unknown neighbor

HELLO packet errors:
 1216  : Netmask mismatch               0     : Hello timer mismatch
 0     : Dead timer mismatch            0     : Extern option mismatch
 1169  : Router id confusion            0     : Virtual neighbor unknown
 0     : NBMA neighbor unknown          0     : Invalid Source Address
```

从上面的输出中，我们可以看到，在R3、R4、R5这三台路由器之间一共发生了五种错误：Router ID冲突（Router id confusion）、子网掩码不匹配（Netmask mismatch）、错误的区域号（Bad area id）、错误的数据包（Bad packet）、错误的虚电路（Bad virtual link）。

在这里我们并没有配置虚电路，在这种情况下错误的虚电路其实就是区域号错误。对于R4来说，它在一个区域号为1的接口上收到了一个区域号为0的OSPF数据包，它会认为这是一个通过虚电路发送过来的数据包。路由器本身没有配置虚电路，就发生了这种错误。

子网掩码错误也是错误的数据包的一部分，我们可以先修正子网掩码的问题再观察是否还有错误的数据包。

首先排除Router ID冲突的问题。我们可以依次查看每台路由器的Router ID来手工找出发生冲突的路由器，也可以通过系统日志来查找。通过**display logbuffer**翻阅路由器当前的系统日志。

```
[R5]display logbuffer
Logging buffer configuration and contents: enabled
Allowed max buffer size: 1024
Actual buffer size: 512
Channel number: 4, Channel name: logbuffer
Dropped messages: 0
Overwritten messages: 0
Current messages: 66

Nov 29 2011 13:38:22+00:00 R5 %%01OSPF/4/CONFLICT_ROUTERID_INTF(l)[0]:OSPF
Router id conflict is detected on interface. (ProcessId=1, RouterId=10.0.5.5,
AreaId=0.0.0.0, InterfaceName=GigabitEthernet0/0/0,  IpAddr=10.0.75.5,
PacketSrcIp=10.0.75.4)
```

从上面可以看到，与R5发生冲突的路由器接口的IP地址是10.0.75.4。查看拓扑，发现10.0.75.4是R4的接口地址。然后查看R4的Router ID，可以看到该路由器的Router ID和R5是一样的。同时还发现R4的区域号配置也有误。

```
[R4]display ospf brief
```

```
        OSPF Process 1 with Router ID 10.0.5.5
                OSPF Protocol Information

 RouterID: 10.0.5.5        Border Router:
 Multi-VPN-Instance is not enabled
 Global DS-TE Mode: Non-Standard IETF Mode
 Graceful-restart capability: disabled
 Helper support capability  : not configured
 Spf-schedule-interval: max 10000ms, start 500ms, hold 1000ms
 Default ASE parameters: Metric: 1 Tag: 1 Type: 2
 Route Preference: 10
 ASE Route Preference: 150
 SPF Computation Count: 13
 RFC 1583 Compatible
 Retransmission limitation is disabled
 Area Count: 1   Nssa Area Count: 0
 ExChange/Loading Neighbors: 0

 Area: 0.0.0.1
 Authtype: None   Area flag: Normal
 SPF scheduled Count: 2
 ExChange/Loading Neighbors: 0

 Interface: 10.0.75.4 (GigabitEthernet0/0/0)
 Cost: 1       State: DR       Type: Broadcast    MTU: 1500
 Priority: 1
 Designated Router: 10.0.75.4
 Backup Designated Router: 0.0.0.0
 Timers: Hello 10 , Dead 40 , Poll  120 , Retransmit 5 , Transmit Delay 1
```

修改R4的Router ID和区域号。

```
[R4]ospf 1 router-id 10.1.4.4
[R4-ospf-1]area 0
[R4-ospf-1-area-0.0.0.0]network 10.0.75.4 0.0.0.0

<R4>reset ospf process
Warning: The OSPF process will be reset. Continue? [Y/N]:y
```

修改完成以后通过命令**reset ospf counter**清空OSPF计数器。

注意reset命令需在用户视图下运行。

```
<R4>reset ospf counters
```

重置后，稍等片刻，再运行display ospf error检查该问题是否消失。

```
<R4>display ospf error

        OSPF Process 1 with Router ID 10.1.4.4
               OSPF error statistics

General packet errors:
 0     : IP: received my own packet     2     : Bad packet
 0     : Bad version                    0     : Bad checksum
 0     : Bad area id                    0     : Drop on unnumbered interface
 0     : Bad virtual link               0     : Bad authentication type
 0     : Bad authentication key         0     : Packet too small
 0     : Packet size > ip length        0     : Transmit error
 0     : Interface down                 0     : Unknown neighbor

HELLO packet errors:
 2     : Netmask mismatch               0     : Hello timer mismatch
 0     : Dead timer mismatch            0     : Extern option mismatch
 0     : Router id confusion            0     : Virtual neighbor unknown
 0     : NBMA neighbor unknown          0     : Invalid Source Address
```

可以看到在修改完配置以后，Route ID冲突和区域号错误的问题消失了，还剩下子网掩码不匹配的问题。为了找出是哪台路由器配置了错误的子网掩码，我们在R4上查看Debug信息。

```
<R4>terminal debugging
Info: Current terminal debugging is on.
<R4>debugging ospf packet hello
Nov 29 2011 14:56:16.720.1+00:00 R4 RM/6/RMDEBUG:
 FileID: 0xd0178024 Line: 2178 Level: 0x20
 OSPF 1: RECV Packet. Interface: GigabitEthernet0/0/0
Nov 29 2011 14:56:16.720.2+00:00 R4 RM/6/RMDEBUG:  Source Address: 10.0.75.3
Nov 29 2011 14:56:16.720.3+00:00 R4 RM/6/RMDEBUG:  Destination Address: 224.0.0.5
Nov 29 2011 14:56:16.720.4+00:00 R4 RM/6/RMDEBUG:  Ver# 2, Type: 1 (Hello)
Nov 29 2011 14:56:16.720.5+00:00 R4 RM/6/RMDEBUG:  Length: 44, Router: 10.0.3.3
Nov 29 2011 14:56:16.720.6+00:00 R4 RM/6/RMDEBUG:  Area: 0.0.0.0, Chksum: 9a18
Nov 29 2011 14:56:16.720.7+00:00 R4 RM/6/RMDEBUG:  AuType: 00
Nov 29 2011 14:56:16.720.8+00:00 R4 RM/6/RMDEBUG:  Key(ascii): 0 0 0 0 0 0 0 0
Nov 29 2011 14:56:16.720.9+00:00 R4 RM/6/RMDEBUG:  Net Mask: 255.255.255.128
Nov 29 2011 14:56:16.720.10+00:00 R4 RM/6/RMDEBUG:  Hello Int: 10, Option: _E_
Nov 29 2011 14:56:16.720.11+00:00 R4 RM/6/RMDEBUG:  Rtr Priority: 1, Dead Int:
40
Nov 29 2011 14:56:16.720.12+00:00 R4 RM/6/RMDEBUG:  DR: 10.0.75.3
```

```
Nov 29 2011 14:56:16.720.13+00:00 R4 RM/6/RMDEBUG:  BDR: 0.0.0.0
Nov 29 2011 14:56:16.730.1+00:00 R4 RM/6/RMDEBUG:  # Attached Neighbors: 0
```

从上面的信息我们可以看出，从10.0.75.3发来的Hello包中子网掩码是255.255.255.128。查看拓扑，发现R3的对应接口配置错误。

```
[R3-GigabitEthernet0/0/0]display this
[V200R001C00SPC200]
#
interface GigabitEthernet0/0/0
 ip address 10.0.75.3 255.255.255.128
#
return
[R3-GigabitEthernet0/0/0]ip address 10.0.75.3 24
```

再次清空OSPF计数器，查看是否还存在错误。

```
<R3>reset ospf counters

<R3>display ospf error

        OSPF Process 1 with Router ID 10.0.3.3
               OSPF error statistics

General packet errors:
 0     : IP: received my own packet     0     : Bad packet
 0     : Bad version                    0     : Bad checksum
 0     : Bad area id                    0     : Drop on unnumbered interface
 0     : Bad virtual link               0     : Bad authentication type
 0     : Bad authentication key         0     : Packet too small
 0     : Packet size > ip length        0     : Transmit error
 0     : Interface down                 0     : Unknown neighbor

HELLO packet errors:
 0     : Netmask mismatch               0     : Hello timer mismatch
 0     : Dead timer mismatch            0     : Extern option mismatch
 0     : Router id confusion            0     : Virtual neighbor unknown
 0     : NBMA neighbor unknown          0     : Invalid Source Address
```

在R3上检查邻居列表，发现各邻居的状态已正常。

```
[R3]display ospf peer brief

        OSPF Process 1 with Router ID 10.0.3.3
                Peer Statistic Information
```

```
----------------------------------------------------------------------------
Area Id          Interface                     Neighbor id      State
0.0.0.0          GigabitEthernet0/0/0            10.1.4.4         Full
0.0.0.0          GigabitEthernet0/0/0            10.0.5.5         Full
0.0.0.1          Serial2/0/0                     10.0.2.2         Full
----------------------------------------------------------------------------
```

接下来我们修改R4的GigabitEthernet 0/0/0接口的Hello间隔为5秒，观察邻居关系是否可以形成。

```
[R4]interface GigabitEthernet 0/0/0
[R4-GigabitEthernet0/0/0]ospf timer hello 5
```

经过约半分钟以后，可以观察到R4的邻居都消失了。

```
[R4]display ospf peer brief

       OSPF Process 1 with Router ID 10.1.4.4
              Peer Statistic Information
----------------------------------------------------------------------------
Area Id          Interface                     Neighbor id      State
----------------------------------------------------------------------------
```

查看OSPF的错误。

```
[R4]display ospf error

       OSPF Process 1 with Router ID 10.1.4.4
             OSPF error statistics

General packet errors:
 0     : IP: received my own packet     2     : Bad packet
 0     : Bad version                    0     : Bad checksum
 0     : Bad area id                    0     : Drop on unnumbered interface
 0     : Bad virtual link               0     : Bad authentication type
 0     : Bad authentication key         0     : Packet too small
 0     : Packet size > ip length        0     : Transmit error
 0     : Interface down                 0     : Unknown neighbor

HELLO packet errors:
 0     : Netmask mismatch               2     : Hello timer mismatch
 0     : Dead timer mismatch            0     : Extern option mismatch
 0     : Router id confusion            0     : Virtual neighbor unknown
 0     : NBMA neighbor unknown          0     : Invalid Source Address
```

可以看到有Hello时间不匹配的错误出现，说明OSPF要求邻居间Hello间隔一样。

取消Hello间隔的修改。再次检查邻居列表。

```
[R4-GigabitEthernet0/0/0]undo ospf timer hello
[R4]display ospf peer brief

       OSPF Process 1 with Router ID 10.1.4.4
              Peer Statistic Information
 ----------------------------------------------------------------------------
 Area Id         Interface                   Neighbor id     State
 0.0.0.0         GigabitEthernet0/0/0          10.0.3.3        Full
 0.0.0.0         GigabitEthernet0/0/0          10.0.5.5        Full
 ----------------------------------------------------------------------------
```

发现邻居关系已恢复正常。

步骤四. OSPF 认证故障排除

在R1和R2上配置基于接口的认证。

其中R1采用simple方式，密钥为123。

R2采用MD5方式，密钥为huawei。

```
[R1]interface Serial 1/0/0
[R1-Serial1/0/0]ospf authentication-mode simple plain 123

[R2]interface Serial 1/0/0
[R2-Serial1/0/0]ospf authentication-mode md5 1 plain huawei
```

配置完成以后在R1上可以查看到OSPF的错误。

```
[R1-Serial1/0/0]display ospf error

       OSPF Process 1 with Router ID 10.1.1.1
             OSPF error statistics

General packet errors:
 0     : IP: received my own packet      15    : Bad packet
 0     : Bad version                     0     : Bad checksum
 0     : Bad area id                     0     : Drop on unnumbered interface
 0     : Bad virtual link                15    : Bad authentication type
 0     : Bad authentication key          0     : Packet too small
```

```
 0     : Packet size > ip length        0     : Transmit error
 0     : Interface down                 0     : Unknown neighbor
```

将R1的认证方式配置为MD5后，查看是否还存在错误。

```
[R1]interface Serial 1/0/0
[R1-Serial1/0/0]ospf authentication-mode md5 1 plain 123
[R1-Serial1/0/0]return
<R1>reset ospf counters
<R1>display ospf error

       OSPF Process 1 with Router ID 10.1.1.1
              OSPF error statistics

General packet errors:
 0     : IP: received my own packet     1     : Bad packet
 0     : Bad version                    0     : Bad checksum
 0     : Bad area id                    0     : Drop on unnumbered interface
 0     : Bad virtual link               1     : Bad authentication type
 0     : Bad authentication key         0     : Packet too small
 0     : Packet size > ip length        0     : Transmit error
 0     : Interface down                 0     : Unknown neighbor
```

可以看到该问题还存在。

将R1的密钥也改成huawei，观察邻居关系。

```
[R1]interface Serial 1/0/0
[R1-Serial1/0/0] ospf authentication-mode md5 1 plain huawei
[R1-Serial1/0/0]quit
[R1]display ospf peer brief

       OSPF Process 1 with Router ID 10.1.1.1
               Peer Statistic Information
 ----------------------------------------------------------------------------
 Area Id          Interface                    Neighbor id      State
 0.0.0.2          Serial1/0/0                   10.0.2.2        Full
 ----------------------------------------------------------------------------
```

可见，R1与R2已建立邻接关系。

步骤五.　虚电路故障排除

为保证区域2与区域0之间的连通性，在R2和R3之间创建虚电路。

```
[R2]ospf 1
[R2-ospf-1]area 1
[R2-ospf-1-area-0.0.0.1]vlink-peer 10.0.3.3

[R3]ospf 1
[R3-ospf-1]area 1
[R3-ospf-1-area-0.0.0.1]vlink-peer 10.0.2.2
```

观察虚电路建立是否正常，以及R1是否学习到了全网路由。

```
[R2]display ospf vlink

         OSPF Process 1 with Router ID 10.0.2.2
                 Virtual Links

 Virtual-link Neighbor-id  -> 10.0.3.3, Neighbor-State: Full

 Interface: 10.0.23.2 (Serial2/0/0)
 Cost: 1562  State: P-2-P  Type: Virtual
 Transit Area: 0.0.0.1
 Timers: Hello 10 , Dead 40 , Retransmit 5 , Transmit Delay 1
 GR State: Normal

[R1]display ip routing-table protocol ospf
Route Flags: R - relay, D - download to fib
------------------------------------------------------------------------------
Public routing table : OSPF
         Destinations : 5        Routes : 5

OSPF routing table status : <Active>
         Destinations : 5        Routes : 5

Destination/Mask    Proto   Pre  Cost      Flags NextHop         Interface

       10.0.2.0/24  OSPF    10   1562        D   10.0.12.2       Serial1/0/0
       10.0.3.0/24  OSPF    10   3124        D   10.0.12.2       Serial1/0/0
       10.0.5.0/24  OSPF    10   3125        D   10.0.12.2       Serial1/0/0
      10.0.23.0/24  OSPF    10   3124        D   10.0.12.2       Serial1/0/0
      10.0.75.0/24  OSPF    10   3125        D   10.0.12.2       Serial1/0/0

OSPF routing table status : <Inactive>
         Destinations : 0        Routes : 0
```

在R1上测试连通性，证实可以到达R5。

```
[R1]ping -c 1 10.0.5.5
  PING 10.0.5.5: 56  data bytes, press CTRL_C to break
    Reply from 10.0.5.5: bytes=56 Sequence=1 ttl=253 time=81 ms

  --- 10.0.5.5 ping statistics ---
    1 packet(s) transmitted
    1 packet(s) received
    0.00% packet loss
    round-trip min/avg/max = 81/81/81 ms
```

由于测试的需要，删除R2的loopback0接口。

```
[R2]undo interface LoopBack 0
```

后来由于一次偶然的事故，路由器重启了。在这里我们通过重启OSPF进程的方法模拟路由器重启。

```
<R2>reset ospf process
Warning: The OSPF process will be reset. Continue? [Y/N]:y
```

这时连接到R1的用户发现自己无法访问区域外的地址。管理员登录到R1上发现无法与R5的Loopback地址通讯。

```
[R1]ping -c 1 10.0.5.5
  PING 10.0.5.5: 56  data bytes, press CTRL_C to break
    Request time out

  --- 10.0.5.5 ping statistics ---
    1 packet(s) transmitted
    0 packet(s) received
    100.00% packet loss
```

检查R2和R3之间的虚电路之后发现状态不正常，同时发现R2的Router ID发生了变化。

```
[R2]display ospf vlink

         OSPF Process 1 with Router ID 10.0.23.2
                 Virtual Links

 Virtual-link Neighbor-id  -> 10.0.3.3, Neighbor-State: Down

 Interface: 10.0.23.2 (Serial2/0/0)
 Cost: 1562  State: P-2-P  Type: Virtual
 Transit Area: 0.0.0.1
```

```
 Timers: Hello 10 , Dead 40 , Retransmit 5 , Transmit Delay 1
 GR State: Normal
```

由于虚电路的建立是基于对端设备的Router ID的。R2的Router ID发生了变化，所以虚电路发生了故障。

通常我们在启动OSPF进程时指定该进程的Router ID，就是为了防止路由器在运行过程中Router ID发生变化。

下面我们将R2的Router ID固定为10.0.2.2，并将Loopback地址添加回去，然后重启OSPF进程。

```
[R2]ospf 1 router-id 10.0.2.2
Info: The configuration succeeded. You need to restart the OSPF process to validate
the new router ID.
[R2-ospf-1]interface LoopBack 0
[R2-LoopBack0]ip address 10.0.2.2 24
[R2-LoopBack0]quit
<R2>reset ospf process
Warning: The OSPF process will be reset. Continue? [Y/N]:y
```

再次查看虚电路状态。

```
[R2]display ospf vlink

       OSPF Process 1 with Router ID 10.0.2.2
              Virtual Links

 Virtual-link Neighbor-id  -> 10.0.3.3, Neighbor-State: Full

 Interface: 10.0.23.2 (Serial2/0/0)
 Cost: 1562  State: P-2-P  Type: Virtual
 Transit Area: 0.0.0.1
 Timers: Hello 10 , Dead 40 , Retransmit 5 , Transmit Delay 1
 GR State: Normal
```

此时虚电路已恢复正常。

管理员出于安全的考虑，在区域0使用了基于区域的认证，启用了MD5对报文进行加密，密钥为huawei。

```
[R3]ospf 1
[R3-ospf-1]area 0
[R3-ospf-1-area-0.0.0.0]authentication-mode md5 1 plain huawei

[R4]ospf 1
```

```
[R4-ospf-1]area 0
[R4-ospf-1-area-0.0.0.0]authentication-mode md5 1 plain huawei

[R5]ospf 1
[R5-ospf-1]area 0
[R5-ospf-1-area-0.0.0.0]authentication-mode md5 1 plain huawei
```

这时，管理员再次发现区域2中的用户无法访问区域外的网络，检查虚电路后发现虚电路又出于故障的状态。

```
[R2]dis ospf vlink

       OSPF Process 1 with Router ID 10.0.2.2
              Virtual Links

 Virtual-link Neighbor-id  -> 10.0.3.3, Neighbor-State: Down

 Interface: 10.0.23.2 (Serial2/0/0)
 Cost: 1562  State: P-2-P  Type: Virtual
 Transit Area: 0.0.0.1
 Timers: Hello 10 , Dead 40 , Retransmit 5 , Transmit Delay 1
```

检查OSPF的错误发现有认证错误发生。

```
[R2]display ospf error

       OSPF Process 1 with Router ID 10.0.2.2
              OSPF error statistics

General packet errors:
 0     : IP: received my own packet     2     : Bad packet
 0     : Bad version                    0     : Bad checksum
 0     : Bad area id                    0     : Drop on unnumbered interface
 0     : Bad virtual link               2     : Bad authentication type
 0     : Bad authentication key         0     : Packet too small
 0     : Packet size > ip length        0     : Transmit error
 0     : Interface down                 0     : Unknown neighbor

HELLO packet errors:
 0     : Netmask mismatch               0     : Hello timer mismatch
 0     : Dead timer mismatch            0     : Extern option mismatch
 0     : Router id confusion            0     : Virtual neighbor unknown
 0     : NBMA neighbor unknown          0     : Invalid Source Address
```

OSPF的虚电路属于区域0。区域0打开了基于区域的认证，虚电路上也需要打开认证。

```
[R2]ospf
[R2-ospf-1]area 0
[R2-ospf-1-area-0.0.0.0]authentication-mode md5 1 plain huawei
```

这时虚电路的状态恢复了正常，R1也能正常访问其他区域了。

```
[R2]display ospf vlink

        OSPF Process 1 with Router ID 10.0.2.2
               Virtual Links

 Virtual-link Neighbor-id  -> 10.0.3.3, Neighbor-State: Full

 Interface: 10.0.23.2 (Serial2/0/0)
 Cost: 1562  State: P-2-P  Type: Virtual
 Transit Area: 0.0.0.1
 Timers: Hello 10 , Dead 40 , Retransmit 5 , Transmit Delay 1
 GR State: Normal

[R1]ping -c 1 10.0.5.5
  PING 10.0.5.5: 56  data bytes, press CTRL_C to break
    Reply from 10.0.5.5: bytes=56 Sequence=1 ttl=253 time=73 ms

  --- 10.0.5.5 ping statistics ---
    1 packet(s) transmitted
    1 packet(s) received
    0.00% packet loss
    round-trip min/avg/max = 73/73/73 ms
```

步骤六. OSPF 路由汇总故障排除

首先在R4上以外部路由的形式引入Loopback 0接口地址，并进行地址汇总，汇总后的子网掩码为16位。

```
[R4]ospf
[R4-ospf-1]import-route direct
[R4-ospf-1]asbr-summary 10.1.0.0 255.255.0.0
```

一段时间之后，管理员在R2上配置了区域间汇总，将R1的Loopback 0接口连接的网段汇总成16位掩码的路由。

```
[R2]ospf
[R2-ospf-1]area 2
[R2-ospf-1-area-0.0.0.2]abr-summary 10.1.0.0 255.255.0.0
```

这时，除了连接到R4的用户以外，全网所有用户均反馈不能访问R4的Loopback地址10.1.4.4。

检查与R4同一区域的路由器R5的路由表发现，若要到达10.1.4.4，匹配到路由条目10.1.0.0/16，而该路由的下一跳是10.0.75.3。

为何会产生这样一个错误的条目呢？

```
[R5]display ip routing-table protocol ospf
Route Flags: R - relay, D - download to fib
------------------------------------------------------------------------------
Public routing table : OSPF
         Destinations : 5       Routes : 5

OSPF routing table status : <Active>
         Destinations : 5       Routes : 5

Destination/Mask    Proto   Pre  Cost   Flags NextHop        Interface

      10.0.2.0/24  OSPF    10   1563     D  10.0.75.3    GigabitEthernet0/0/0
      10.0.3.0/24  OSPF    10   1        D  10.0.75.3    GigabitEthernet0/0/0
     10.0.12.0/24  OSPF    10   3125     D  10.0.75.3    GigabitEthernet0/0/0
     10.0.23.0/24  OSPF    10   1563     D  10.0.75.3    GigabitEthernet0/0/0
      10.1.0.0/16  OSPF    10   3125     D  10.0.75.3    GigabitEthernet0/0/0

OSPF routing table status : <Inactive>
         Destinations : 0       Routes : 0
```

我们先来观察一下R5的LSDB。

```
[R5]display ospf lsdb

         OSPF Process 1 with Router ID 10.0.5.5
                 Link State Database

                        Area: 0.0.0.0
 Type      LinkState ID   AdvRouter          Age  Len   Sequence   Metric
 Router     10.0.5.5       10.0.5.5           214  48    80000025       0
 Router     10.0.3.3       10.0.3.3          1246  48    80000024       1
 Router     10.0.2.2       10.0.2.2          1247  36    80000005    1562
 Router     10.1.4.4       10.1.4.4           648  36    8000000D       1
```

```
Network        10.0.75.4      10.1.4.4          206  36    80000004       0
Sum-Net     10.0.12.0      10.0.2.2          916  28    80000002    1562
Sum-Net     10.0.3.0       10.0.3.3          893  28    80000008       0
Sum-Net     10.0.3.0       10.0.2.2          916  28    80000002    1562
Sum-Net     10.0.2.0       10.0.3.3          919  28    80000003    1562
Sum-Net     10.0.2.0       10.0.2.2          916  28    80000002       0
Sum-Net     10.1.0.0       10.0.2.2          538  28    80000001    1562
Sum-Net     10.0.23.0      10.0.3.3          893  28    80000008    1562
Sum-Net     10.0.23.0      10.0.2.2          917  28    80000002    1562


             AS External Database
Type      LinkState ID    AdvRouter          Age  Len   Sequence   Metric
External       10.0.75.0      10.1.4.4          649  36    80000001       1
External       10.1.0.0       10.1.4.4          620  36    80000001       2
```

在LSDB中我们看到有2条描述10.1.0.0的路由，接下来查看LSA的详细信息。下面这条第三类LSA是由R2始发的，而这条第五类LSA是由R5始发的。这两条LSA描述了一个完全相同的网段信息。

```
[R5]display ospf lsdb summary 10.1.0.0

       OSPF Process 1 with Router ID 10.0.5.5
                    Area: 0.0.0.0
              Link State Database


 Type      : Sum-Net
 Ls id     : 10.1.0.0
 Adv rtr    : 10.0.2.2
 Ls age    : 767
 Len       : 28
 Options    :  E
 seq#      : 80000001
 chksum    : 0xa380
 Net mask  : 255.255.0.0
 Tos 0  metric: 1562
 Priority  : Low

[R5]display ospf lsdb ase 10.1.0.0

       OSPF Process 1 with Router ID 10.0.5.5
              Link State Database


 Type      : External
```

```
  Ls id     : 10.1.0.0
  Adv rtr   : 10.1.4.4
  Ls age    : 871
  Len       : 36
  Options   :  E
  seq#      : 80000001
  chksum    : 0xe3cd
  Net mask  : 255.255.0.0
  TOS 0  Metric: 2
  E type    : 2
  Forwarding Address : 0.0.0.0
  Tag       : 1
  Priority  : Low
```

在OSPF中，第三类LSA始终优于第五类LSA，所以在R5路由表里出现的10.1.0.0/16这条路由的下一跳会是R3。

为了避免这类问题的发生，我们在R4上取消原来对外部路由的汇总，这样这条路由就会再次在其他路由器的路由表中出现。

```
[R4-ospf-1]undo asbr-summary 10.1.0.0 255.255.0.0

[R5]display ip routing-table protocol os
Route Flags: R - relay, D - download to fib
------------------------------------------------------------------------------
Public routing table : OSPF
       Destinations : 6       Routes : 6

OSPF routing table status : <Active>
       Destinations : 6       Routes : 6

Destination/Mask    Proto   Pre  Cost   Flags NextHop       Interface

      10.0.2.0/24  OSPF    10   1563     D   10.0.75.3    GigabitEthernet0/0/0
      10.0.3.0/24  OSPF    10   1        D   10.0.75.3    GigabitEthernet0/0/0
     10.0.12.0/24  OSPF    10   3125     D   10.0.75.3    GigabitEthernet0/0/0
     10.0.23.0/24  OSPF    10   1563     D   10.0.75.3    GigabitEthernet0/0/0
      10.1.0.0/16  OSPF    10   3125     D   10.0.75.3    GigabitEthernet0/0/0
      10.1.4.4/24  O_ASE   150  1        D   10.0.75.4    GigabitEthernet0/0/0

OSPF routing table status : <Inactive>
       Destinations : 0       Routes : 0
```

这时我们可以看到，在R5上已学习到了一条关于10.1.4.4/24正确的路由。

这时我们在R1上测试连通性。

```
[R1]ping -c 1 10.1.4.4
  PING 10.1.4.4: 56  data bytes, press CTRL_C to break
    Reply from 10.1.4.4: bytes=56 Sequence=1 ttl=253 time=71 ms

  --- 10.1.4.4 ping statistics ---
    1 packet(s) transmitted
    1 packet(s) received
    0.00% packet loss
    round-trip min/avg/max = 71/71/71 ms
```

可见，网络恢复正常。

附加实验: 思考并验证

可否在一个区域中即打开基于区域的认证，又打开基于接口的认证？

非骨干区域的区域号可否一样？

最终设备配置

```
<R1>display current-configuration
[V200R001C00SPC200]
#
 sysname R1
#
interface Serial1/0/0
 link-protocol ppp
 ip address 10.0.12.1 255.255.255.0
 ospf authentication-mode md5 1 plain huawei
#
interface LoopBack0
 ip address 10.1.1.1 255.255.255.0
 ospf network-type broadcast
#
ospf 1 router-id 10.1.1.1
 area 0.0.0.2
  network 10.0.12.1 0.0.0.0
  network 10.1.1.1 0.0.0.0
#
return
```

```
<R2>display current-configuration
[V200R001C00SPC200]
#
 sysname R2
#
interface Serial1/0/0
 link-protocol ppp
 ip address 10.0.12.2 255.255.255.0
 ospf authentication-mode md5 1 plain huawei
#
interface LoopBack0
 ip address 10.0.2.2 255.255.255.0
 ospf network-type broadcast
#
ospf 1 router-id 10.0.2.2
 area 0.0.0.0
  authentication-mode md5 1 plain huawei
 area 0.0.0.1
  network 10.0.23.2 0.0.0.0
  network 10.0.2.2 0.0.0.0
  vlink-peer 10.0.3.3
 area 0.0.0.2
  abr-summary 10.1.0.0 255.255.0.0
  network 10.0.12.2 0.0.0.0
#
return
```

```
<R3>display current-configuration
[V200R001C00SPC200]
#
 sysname R3
#
interface Serial2/0/0
 link-protocol ppp
 ip address 10.0.23.3 255.255.255.0
#
interface GigabitEthernet0/0/0
 ip address 10.0.75.3 255.255.255.0
#
interface LoopBack0
 ip address 10.0.3.3 255.255.255.0
 ospf network-type broadcast
#
```

```
ospf 1 router-id 10.0.3.3
 area 0.0.0.0
  authentication-mode md5 1 plain huawei
  network 10.0.75.3 0.0.0.0
 area 0.0.0.1
  network 10.0.23.3 0.0.0.0
  network 10.0.3.3 0.0.0.0
  vlink-peer 10.0.2.2
#
return
```

```
<R4>display current-configuration
[V200R001C00SPC200]
#
 sysname R4
#
interface GigabitEthernet0/0/0
 ip address 10.0.75.4 255.255.255.0
#
interface LoopBack0
 ip address 10.1.4.4 255.255.255.0
#
ospf 1 router-id 10.1.4.4
 import-route direct
 area 0.0.0.0
  authentication-mode md5 1 plain huawei
  network 10.0.75.4 0.0.0.0
#
return
```

```
<R5>display current-configuration
[V200R001C00SPC200]
#
 sysname R5
#
interface GigabitEthernet0/0/0
 ip address 10.0.75.5 255.255.255.0
#
interface LoopBack0
 ip address 10.0.5.5 255.255.255.0
 ospf network-type broadcast
#
ospf 1 router-id 10.0.5.5
```

```
 area 0.0.0.0
  authentication-mode md5 1 plain huawei
  network 10.0.75.5 0.0.0.0
  network 10.0.5.5 0.0.0.0
#
Return
```

实验 2-7 OSPF 高级特性

学习目的

- 掌握在NBMA网络中手工配置OSPF邻居的方法
- 掌握在NBMA网络中影响DR选举的方法
- 掌握在NBMA网络中配置OSPF的特点
- 掌握在FR中设置广播型网络，使用OSPF的方法
- 掌握在FR中设置P2MP型网络，使用OSPF的方法
- 掌握混合使用P2MP和P2P网络中配置OSPF的方法
- 掌握在FR中建立子接口设置P2P型网络使用OSPF的方法

拓扑图

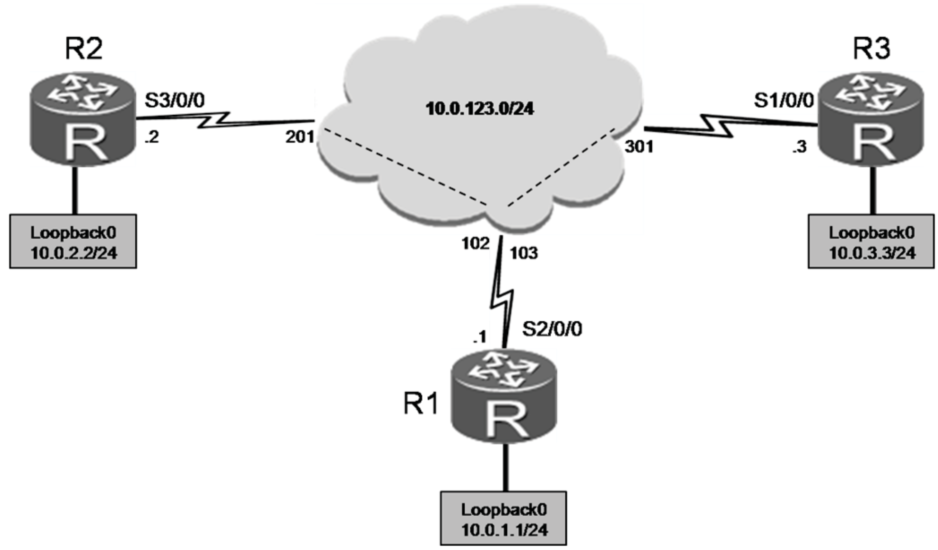


图2-7 OSPF 高级特性

场景

你是公司的网络管理员。公司的网络采用了OSPF协议作为路由协议。公司有三个分支机构，分别有R1、R2、R3三台路由器。出于成本的考虑，在R1和R2之间，R1和R3之间各租用一条虚电路，在R2和R3之间没有虚电路。首先通过配置使OSPF在NBMA网络上运行并观察使用情况，然后再分别将网络修改为广播型、P2MP型，P2MP-P2P混合型以及点对点类型来运行OSPF。

学习任务

步骤一.　基础 FR 互联配置与 IP 编址

给所有路由器配置IP地址和掩码。配置时注意所有的Loopback接口配置掩码均为24位，模拟成一个单独的网段。

默认情况下路由器开启帧中继反向ARP特性（Inverse ARP），需要关闭该特性，并使用手工映射的方法建立R1与R2以及R1与R3之间的ARP映射表。

默认情况下，帧中继线路不能传递广播，为了能在本实验中OSPF邻居发现的正常进行，我们在做帧中继地址映射的时候加上Broadcast参数，允许广播报文通过。

```
<R1>system-view
Enter system view, return user view with Ctrl+Z.
[R1]interface Serial 2/0/0
[R1-Serial2/0/0]link-protocol fr
Warning: The encapsulation protocol of the link will be changed. Continue? [Y/N]:y
[R1-Serial2/0/0]ip address 10.0.123.1 24
[R1-Serial2/0/0]undo fr inarp
[R1-Serial2/0/0]fr map ip 10.0.123.2 102 broadcast
[R1-Serial2/0/0]fr map ip 10.0.123.3 103 broadcast
[R1-Serial2/0/0]interface LoopBack 0
[R1-LoopBack0]ip address 10.0.1.1 24

<R2>system-view
Enter system view, return user view with Ctrl+Z.
[R2]interface Serial 3/0/0
[R2-Serial3/0/0]link-protocol fr
Warning: The encapsulation protocol of the link will be changed. Continue? [Y/N]:y
[R2-Serial3/0/0]ip address 10.0.123.2 24
[R2-Serial3/0/0]undo fr inarp
[R2-Serial3/0/0]fr map ip 10.0.123.1 201 broadcast
[R2-Serial3/0/0]interface LoopBack 0
[R2-LoopBack0]ip address 10.0.2.2 24

<R3>system-view
Enter system view, return user view with Ctrl+Z.
[R3]interface s1/0/0
[R3-Serial1/0/0]link-protocol fr
Warning: The encapsulation protocol of the link will be changed. Continue? [Y/N]:y
[R3-Serial1/0/0]ip address 10.0.123.3 24
[R3-Serial1/0/0]undo fr inarp
[R3-Serial1/0/0]fr map ip 10.0.123.1 301 broadcast
[R3-Serial1/0/0]interface LoopBack 0
[R3-LoopBack0]ip address 10.0.3.3 24
```

配置完成后，**display fr map-info**检查FR的地址映射信息，测试链路的连通性。

```
[R1]display fr map-info
Map Statistics for interface Serial2/0/0 (DTE)
  DLCI = 102, IP 10.0.123.2, Serial2/0/0
    create time = 2011/11/30 09:06:43, status = ACTIVE
    encapsulation = ietf, vlink = 3, broadcast
  DLCI = 103, IP 10.0.123.3, Serial2/0/0
    create time = 2011/11/30 09:06:53, status = ACTIVE
```

```
  encapsulation = ietf, vlink = 4, broadcast

[R1]ping -c 1 10.0.123.2
 PING 10.0.123.2: 56  data bytes, press CTRL_C to break
  Reply from 10.0.123.2: bytes=56 Sequence=1 ttl=255 time=66 ms

 --- 10.0.123.2 ping statistics ---
  1 packet(s) transmitted
  1 packet(s) received
  0.00% packet loss
  round-trip min/avg/max = 66/66/66 ms

[R1]ping -c 1 10.0.123.3
 PING 10.0.123.3: 56  data bytes, press CTRL_C to break
  Reply from 10.0.123.3: bytes=56 Sequence=1 ttl=255 time=56 ms

 --- 10.0.123.3 ping statistics ---
  1 packet(s) transmitted
  1 packet(s) received
  0.00% packet loss
  round-trip min/avg/max = 56/56/56 ms
```

步骤二.　配置 NBMA 类型的 OSPF 网络

配置10.0.123.0/24及各路由器Loopback 0接口地址属于OSPF区域0。对所有路由器的Loopback0接口，修改其OSPF网络类型为Broadcast类型，使用Loopback 0的地址作为Router ID。

注意在使用network命令时，通配符掩码使用0.0.0.0。

在帧中继网络中，OSPF默认的网络类型为NBMA，对于NBMA网络来说，要求手工配置OSPF的邻居，配置完成以后检查各路由器邻居关系。

```
[R1]ospf 1 router-id 10.0.123.1
[R1-ospf-1]area 0
[R1-ospf-1-area-0.0.0.0]network 10.0.123.1 0.0.0.0
[R1-ospf-1-area-0.0.0.0]network 10.0.1.1 0.0.0.0
[R1-ospf-1-area-0.0.0.0]quit
[R1-ospf-1]peer 10.0.123.2
[R1-ospf-1]peer 10.0.123.3
[R1-ospf-1]interface LoopBack 0
[R1-LoopBack0]ospf network-type broadcast
```

```
[R2]ospf 1 router-id 10.0.2.2
[R2-ospf-1]area 0
[R2-ospf-1-area-0.0.0.0]network 10.0.123.2 0.0.0.0
[R2-ospf-1-area-0.0.0.0]network 10.0.2.2 0.0.0.0
[R2-ospf-1-area-0.0.0.0]quit
[R2-ospf-1]peer 10.0.123.1
[R2-ospf-1]int LoopBack 0
[R2-LoopBack0]ospf network-type broadcast

[R3]ospf 1 router-id 10.0.3.3
[R3-ospf-1]area 0
[R3-ospf-1-area-0.0.0.0]network 10.0.123.3 0.0.0.0
[R3-ospf-1-area-0.0.0.0]network 10.0.3.3 0.0.0.0
[R3-ospf-1-area-0.0.0.0]quit
[R3-ospf-1]peer 10.0.123.1
[R3-ospf-1]interface LoopBack 0
[R3-LoopBack0]ospf network-type broadcast
```

由于R1的OSPF最早配置，所以R1是10.0.123.0这个网段的DR。这时我们通过**reset ospf process**重启R1的OSPF进程。

```
<R1>reset ospf process
Warning: The OSPF process will be reset. Continue? [Y/N]:y

[R2]display ospf peer

        OSPF Process 1 with Router ID 10.0.2.2
               Neighbors

 Area 0.0.0.0 interface 10.0.123.2(Serial3/0/0)'s neighbors
 Router ID: 10.0.123.1      Address: 10.0.123.1
   State: Full  Mode:Nbr is  Master  Priority: 1
   DR: 10.0.123.2  BDR: 10.0.123.1  MTU: 0
   Dead timer due in 93  sec
   Retrans timer interval: 6
   Neighbor is up for 00:01:23
   Authentication Sequence: [ 0 ]
```

这时，看到R2担当了DR的位置。在R2上查看OSPF路由表。

```
[R2]dis ip routing-table protocol ospf
Route Flags: R - relay, D - download to fib
------------------------------------------------------------------------------
Public routing table : OSPF
```

```
        Destinations : 1       Routes : 1

OSPF routing table status : <Active>
        Destinations : 1       Routes : 1

Destination/Mask    Proto   Pre  Cost     Flags NextHop        Interface

      10.0.1.0/24  OSPF    10   1562       D   10.0.123.1     Serial3/0/0

OSPF routing table status : <Inactive>
        Destinations : 0       Routes : 0
```

现在可以发现在R2中仅存在一条OSPF路由，为到达R1的Loopback 0连接网段的路由。R2没有学习到R3的Loopback 0所在网段的路由。这是什么原因呢？

NBMA网络本身要求全互联。在本次实验中，R2和R3之间不存在虚电路，没有直接的邻接关系。而这时R2担当DR，所以R3的路由信息是没办法传递给R2。

因此，在这种场景中，我们必须保证R1始终成为DR。我们通过修改R2和R3接口的OSPF优先级来保证R1始终成为DR。

在OSPF中，接口优先级为0的路由器始终不参加DR/BDR的选举。

```
[R2]interface s3/0/0
[R2-Serial3/0/0]ospf dr-priority 0

[R3]interface Serial 1/0/0
[R3-Serial1/0/0]ospf dr-priority 0
```

再次检查OSPF路由表，查看路由是否有缺失；

```
[R2]display ip routing-table protocol ospf
Route Flags: R - relay, D - download to fib
------------------------------------------------------------------------------
Public routing table : OSPF
        Destinations : 2       Routes : 2

OSPF routing table status : <Active>
        Destinations : 2       Routes : 2

Destination/Mask    Proto   Pre  Cost     Flags NextHop        Interface

      10.0.1.0/24  OSPF    10   1562       D   10.0.123.1     Serial3/0/0
      10.0.3.0/24  OSPF    10   1562       D   10.0.123.3     Serial3/0/0
```

```
OSPF routing table status : <Inactive>
        Destinations : 0        Routes : 0
```

我们在路由表里已能看到了到达R3的Loopback接口网段的路由，然后在R2上检查连通性。

```
[R2]ping -c 1 10.0.3.3
  PING 10.0.3.3: 56  data bytes, press CTRL_C to break
    Request time out

  --- 10.0.3.3 ping statistics ---
    1 packet(s) transmitted
    0 packet(s) received
    100.00% packet loss
```

我们发现R2无法访问R3的Loopback0接口的地址，这又是什么原因呢？

检查路由表，发现要到达10.0.3.3的路由的下一跳是10.0.123.3。

检查到达该下一跳地址的连通性。

```
[R2]ping -c 1 10.0.123.3
  PING 10.0.123.3: 56  data bytes, press CTRL_C to break
    Request time out

  --- 10.0.123.3 ping statistics ---
    1 packet(s) transmitted
    0 packet(s) received
    100.00% packet loss
```

地址10.0.123.3和R1的接口地址10.0.123.2在同一网段。查看帧中继的映射表。

```
[R2]display fr map-info
Map Statistics for interface Serial3/0/0 (DTE)
  DLCI = 201, IP 10.0.123.1, Serial3/0/0
    create time = 2011/11/30 10:03:37, status = ACTIVE
    encapsulation = ietf, vlink = 1, broadcast
```

发现仅存在到达10.0.123.1的映射，没有到达10.0.123.3的映射关系。

这时我们手工增加R2到R3接口地址的映射，以及R3到R2接口地址的映射。

```
[R2]interface Serial 3/0/0
[R2-Serial3/0/0]fr map ip 10.0.123.3 201
[R2-Serial3/0/0]quit
```

```
[R3]interface Serial 1/0/0
[R3-Serial1/0/0]fr map ip 10.0.123.2 301
[R3-Serial1/0/0]quit
```

再次测试R2与R3之间的连通性。

```
[R2]ping -c 1 10.0.3.3
  PING 10.0.3.3: 56  data bytes, press CTRL_C to break
    Reply from 10.0.3.3: bytes=56 Sequence=1 ttl=254 time=122 ms

  --- 10.0.3.3 ping statistics ---
    1 packet(s) transmitted
    1 packet(s) received
    0.00% packet loss
    round-trip min/avg/max = 122/122/122 ms
```

这时R2已能访问R3。

步骤三. 配置广播类型的 OSPF 网络

默认情况下，帧中继线路不能传递广播。为了能在OSPF中使用广播这种网络类型，刚才我们在做帧中继地址映射的时候加上Broadcast参数，允许广播在帧中继线路上通过。

配置OSPF的网络类型为广播，使OSPF在FR接口上，以广播的形式工作。

```
[R1]interface Serial 2/0/0
[R1-Serial2/0/0]ospf network-type broadcast

[R2]interface Serial 3/0/0
[R2-Serial3/0/0]ospf network-type broadcast

[R3]interface Serial 1/0/0
[R3-Serial1/0/0]ospf network-type broadcast
```

在广播型网络中，是不需要手工配置邻居的。所以我们在OSPF进程下删除手工配置的邻居。

```
[R1]ospf 1
[R1-ospf-1]undo peer 10.0.123.2
[R1-ospf-1]undo peer 10.0.123.3

[R2]ospf 1
```

```
[R2-ospf-1]undo peer 10.0.123.1

[R3]ospf 1
[R3-ospf-1]undo peer 10.0.123.1
```

在R1上检查邻居关系，并在R2上查看路由表，测试连通性。

```
[R1]display ospf peer brief

         OSPF Process 1 with Router ID 10.0.123.1
                  Peer Statistic Information
 ----------------------------------------------------------------------------
 Area Id          Interface                      Neighbor id      State
 0.0.0.0          Serial2/0/0                     10.0.2.2        Full
 0.0.0.0          Serial2/0/0                     10.0.3.3        Full
 ----------------------------------------------------------------------------

[R2]display ip routing-table protocol ospf
Route Flags: R - relay, D - download to fib
----------------------------------------------------------------------------
Public routing table : OSPF
         Destinations : 2       Routes : 2

OSPF routing table status : <Active>
         Destinations : 2       Routes : 2

Destination/Mask    Proto   Pre  Cost      Flags NextHop         Interface

      10.0.1.0/24  OSPF    10   1562        D   10.0.123.1      Serial3/0/0
      10.0.3.0/24  OSPF    10   1562        D   10.0.123.3      Serial3/0/0

OSPF routing table status : <Inactive>
         Destinations : 0       Routes : 0
```

这时网络已工作正常。

注意，到达网络10.0.3.0/24的下一跳是10.0.123.3，和刚才设置为NBMA的网络类型的结果是一样的。所以对于广播型网络，在R2和R3的接口地址之间还是需要存在帧中继的映射关系的。

在R2上测试网络是否正常。

```
[R2]ping -c 1 10.0.3.3
  PING 10.0.3.3: 56  data bytes, press CTRL_C to break
    Reply from 10.0.3.3: bytes=56 Sequence=1 ttl=254 time=114 ms
```

```
 --- 10.0.3.3 ping statistics ---
   1 packet(s) transmitted
   1 packet(s) received
   0.00% packet loss
   round-trip min/avg/max = 114/114/114 ms
```

步骤四. 配置 P2MP 类型的 OSPF 网络

在P2MP这种网络类型中，我们同样不需要手工配置邻居。

把各接口的网络类型修改为P2MP，同时在接口下将设置DR优先级的配置删除。

在P2MP这种类型的网络中，OSPF是不需要进行DR/BDR的选举的。

```
[R1]interface Serial 2/0/0
[R1-Serial2/0/0]ospf network-type p2mp

[R2]interface Serial 3/0/0
[R2-Serial3/0/0]undo ospf dr-priority
[R2-Serial3/0/0]ospf network-type p2mp

[R3]interface Serial 1/0/0
[R3-Serial1/0/0]undo ospf dr-priority
[R3-Serial1/0/0]ospf network-type p2mp
```

在R1上查看邻居关系。

```
[R1]display ospf peer  brief

       OSPF Process 1 with Router ID 10.0.123.1
              Peer Statistic Information
 ----------------------------------------------------------------------------
 Area Id         Interface                     Neighbor id      State
 0.0.0.0         Serial2/0/0                    10.0.2.2        Full
 0.0.0.0         Serial2/0/0                    10.0.3.3        Full
 ----------------------------------------------------------------------------
```

在R1和R2上分别检查路由表，可以看到路由信息均正常传递。

```
[R1]display ip routing-table protocol ospf
Route Flags: R - relay, D - download to fib
----------------------------------------------------------------------------
```

```
Public routing table : OSPF
        Destinations : 4       Routes : 4

OSPF routing table status : <Active>
        Destinations : 2       Routes : 2

Destination/Mask    Proto   Pre  Cost     Flags NextHop        Interface

      10.0.2.0/24  OSPF    10   1562       D   10.0.123.2     Serial2/0/0
      10.0.3.0/24  OSPF    10   1562       D   10.0.123.3     Serial2/0/0

OSPF routing table status : <Inactive>
        Destinations : 2       Routes : 2

Destination/Mask    Proto   Pre  Cost     Flags NextHop        Interface

    10.0.123.2/32  OSPF    10   1562           10.0.123.2     Serial2/0/0
    10.0.123.3/32  OSPF    10   1562           10.0.123.3     Serial2/0/0

[R2]display ip routing-table protocol ospf
Route Flags: R - relay, D - download to fib
------------------------------------------------------------------------------
Public routing table : OSPF
        Destinations : 4       Routes : 4

OSPF routing table status : <Active>
        Destinations : 2       Routes : 2

Destination/Mask    Proto   Pre  Cost     Flags NextHop        Interface

      10.0.1.0/24  OSPF    10   1562       D   10.0.123.1     Serial3/0/0
      10.0.3.0/24  OSPF    10   3124       D   10.0.123.1     Serial3/0/0

OSPF routing table status : <Inactive>
        Destinations : 2       Routes : 2

Destination/Mask    Proto   Pre  Cost     Flags NextHop        Interface

    10.0.123.1/32  OSPF    10   1562           10.0.123.1     Serial3/0/0
    10.0.123.3/32  OSPF    10   3124           10.0.123.1     Serial3/0/0
```

观察R2的路由表我们可以发现，到达网段10.0.3.0/24的下一跳变成了10.0.123.1。这样，实际上在R2上只要有对10.0.123.1这个地址帧中继映射就可

以了。

先删除多余的地址映射，再测试连通性。

```
[R2]interface Serial 3/0/0
[R2-Serial3/0/0]undo fr map ip 10.0.123.3 201

[R3]interface Serial 1/0/0
[R3-Serial1/0/0]undo fr map ip 10.0.123.2 301
```

在R2上验证连通性，说明R2到R3的通信正常。

```
[R2]ping -c 1 10.0.3.3
  PING 10.0.3.3: 56  data bytes, press CTRL_C to break
    Reply from 10.0.3.3: bytes=56 Sequence=1 ttl=254 time=119 ms

  --- 10.0.3.3 ping statistics ---
    1 packet(s) transmitted
    1 packet(s) received
    0.00% packet loss
    round-trip min/avg/max = 119/119/119 ms
```

在R2上再检查一下删除10.0.123.3映射后路由表有什么变化。

```
[R2-Serial3/0/0]disp ip routing-table protocol ospf
Route Flags: R - relay, D - download to fib
------------------------------------------------------------------------------
Public routing table : OSPF
         Destinations : 4       Routes : 4

OSPF routing table status : <Active>
         Destinations : 3       Routes : 3

Destination/Mask    Proto   Pre  Cost      Flags NextHop         Interface


       10.0.1.0/24  OSPF    10   1562        D   10.0.123.1      Serial3/0/0
       10.0.3.0/24  OSPF    10   3124        D   10.0.123.1      Serial3/0/0
     10.0.123.3/32  OSPF    10   3124        D   10.0.123.1      Serial3/0/0

OSPF routing table status : <Inactive>
         Destinations : 1       Routes : 1

Destination/Mask    Proto   Pre  Cost      Flags NextHop         Interface


     10.0.123.1/32  OSPF    10   1562            10.0.123.1      Serial3/0/0
```

这时可以发现刚才10.0.123.3/32不是活跃状态的，因为10.0.123.3/32是以直连路由的形式出现在路由表里的。现在删除帧中继到达10.0.123.3的映射以后，10.0.123.3/32便以OSPF的形式出现在路由表里了。

步骤五. 配置 P2MP 和 P2P 混合的 OSPF 网络

P2MP和P2P两种网络类型可混合存在。

将R2、R3的网络类型更改为P2P，R1的网络类型保持P2MP不变。

```
[R2]interface Serial 3/0/0
[R2-Serial3/0/0]ospf network-type p2p

[R3]interface Serial 1/0/0
[R3-Serial1/0/0]ospf network-type p2p
```

这时我们可以看到路由器之间的邻居关系都消失了，等候一段时间以后也没有再建立。观察OSPF的错误会发现有Hello间隔不匹配的问题出现。

```
Nov 30 2011 14:16:10+00:00 R2 %%01OSPF/3/NBR_CHG_DOWN(l)[0]:Neighbor
event:neighbor state changed to Down. (ProcessId=1, NeighborAddress=10.0.123.1,
NeighborEvent=KillNbr, NeighborPreviousState=Full, NeighborCurrentState=Down)

[R2]display ospf error

        OSPF Process 1 with Router ID 10.0.2.2
              OSPF error statistics

General packet errors:
 0    : IP: received my own packet     6    : Bad packet
 0    : Bad version                    0    : Bad checksum
 0    : Bad area id                    0    : Drop on unnumbered interface
 0    : Bad virtual link               0    : Bad authentication type
 0    : Bad authentication key         0    : Packet too small
 0    : Packet size > ip length        0    : Transmit error
 7    : Interface down                 0    : Unknown neighbor

HELLO packet errors:
 0    : Netmask mismatch               6    : Hello timer mismatch
 0    : Dead timer mismatch            0    : Extern option mismatch
 0    : Router id confusion            0    : Virtual neighbor unknown
 0    : NBMA neighbor unknown          0    : Invalid Source Address
```

对于P2MP网络而言，默认的Hello间隔是30秒。而对于P2P，默认的Hello间隔是10秒。

在这个实验中，调整R1的Hello间隔。

```
[R1]interface Serial 2/0/0
[R1-Serial2/0/0]ospf timer hello 10
```

等待约半分钟后，再次观察邻居关系是否能建立。

```
[R1]display ospf peer brief

        OSPF Process 1 with Router ID 10.0.123.1
                Peer Statistic Information
 ----------------------------------------------------------------------------
 Area Id         Interface                     Neighbor id      State
 0.0.0.0         Serial2/0/0                    10.0.2.2        Full
 0.0.0.0         Serial2/0/0                    10.0.3.3        Full
 ----------------------------------------------------------------------------
```

可以看到路由器之间又形成了邻居关系。

接着检查路由器之间的路由信息传递是否正常，首先在R1上查看路由表。

```
[R1]display ip routing-table protocol ospf
Route Flags: R - relay, D - download to fib
----------------------------------------------------------------------------
Public routing table : OSPF
        Destinations : 3       Routes : 4

OSPF routing table status : <Active>
        Destinations : 2       Routes : 2

Destination/Mask    Proto  Pre  Cost     Flags NextHop        Interface

      10.0.2.0/24  OSPF    10   1562       D   10.0.123.2     Serial2/0/0
      10.0.3.0/24  OSPF    10   1562       D   10.0.123.3     Serial2/0/0

OSPF routing table status : <Inactive>
        Destinations : 1       Routes : 2

Destination/Mask    Proto  Pre  Cost     Flags NextHop        Interface

    10.0.123.0/24  OSPF    10   3124           10.0.123.2     Serial2/0/0
    10.0.123.0/24  OSPF    10   3124           10.0.123.3     Serial2/0/0
```

可以看到R1上有R2和R3的Loopback地址所在网段的路由。

查看R2的路由表。

```
[R2]display ip routing-table protocol ospf
Route Flags: R - relay, D - download to fib
------------------------------------------------------------------------------
Public routing table : OSPF
        Destinations : 3       Routes : 3

OSPF routing table status : <Active>
        Destinations : 2       Routes : 2

Destination/Mask    Proto   Pre  Cost     Flags NextHop        Interface

      10.0.1.0/24  OSPF    10   1562       D   10.0.123.1     Serial3/0/0
      10.0.3.0/24  OSPF    10   3124       D   10.0.123.1     Serial3/0/0

OSPF routing table status : <Inactive>
        Destinations : 1       Routes : 1

Destination/Mask    Proto   Pre  Cost     Flags NextHop        Interface

    10.0.123.1/32  OSPF    10   1562           10.0.123.1     Serial3/0/0
```

在R2上的路由表存在到达R1和R3的路由，但是否能直接访问到呢？

```
[R2]ping -c 1 10.0.3.3
  PING 10.0.3.3: 56  data bytes, press CTRL_C to break
    Request time out

  --- 10.0.3.3 ping statistics ---
    1 packet(s) transmitted
    0 packet(s) received
    100.00% packet loss

[R2]ping -c 1 10.0.1.1
  PING 10.0.1.1: 56  data bytes, press CTRL_C to break
    Reply from 10.0.1.1: bytes=56 Sequence=1 ttl=255 time=63 ms

  --- 10.0.1.1 ping statistics ---
    1 packet(s) transmitted
    1 packet(s) received
    0.00% packet loss
    round-trip min/avg/max = 63/63/63 ms
```

这时我们发现R2并不能直接访问到R3，但能直接访问到R1。跟踪到达10.0.3.3的数据包在哪一跳被丢弃。

```
[R2]tracert 10.0.3.3
 traceroute to  10.0.3.3(10.0.3.3), max hops: 30 ,packet length: 40,press CTRL_C
to break
 1 10.0.123.1 61 ms  42 ms  42 ms
 2  *  *  *
 ...
```

上面的结果说明数据包已经到达了R1，但到达R3之后被丢弃了，我们检查R3的全局路由表。

```
[R3]display ip routing-table
Route Flags: R - relay, D - download to fib
------------------------------------------------------------------------------
Routing Tables: Public
        Destinations : 13      Routes : 13

Destination/Mask    Proto  Pre  Cost   Flags NextHop        Interface

      10.0.1.0/24   OSPF   10   1562    D   10.0.123.1     Serial1/0/0
      10.0.2.0/24   OSPF   10   3124    D   10.0.123.1     Serial1/0/0
      10.0.3.0/24   Direct  0   0       D   10.0.3.3       LoopBack0
      10.0.3.3/32   Direct  0   0       D   127.0.0.1      InLoopBack0
    10.0.3.255/32   Direct  0   0       D   127.0.0.1      InLoopBack0
    10.0.123.0/24   Direct  0   0       D   10.0.123.3     Serial1/0/0
    10.0.123.1/32   Direct  0   0       D   10.0.123.1     Serial1/0/0
    10.0.123.3/32   Direct  0   0       D   127.0.0.1      InLoopBack0
  10.0.123.255/32   Direct  0   0       D   127.0.0.1      InLoopBack0
     127.0.0.0/8    Direct  0   0       D   127.0.0.1      InLoopBack0
     127.0.0.1/32   Direct  0   0       D   127.0.0.1      InLoopBack0
127.255.255.255/32  Direct  0   0       D   127.0.0.1      InLoopBack0
255.255.255.255/32  Direct  0   0       D   127.0.0.1      InLoopBack0
```

这时我们应该注意到刚才在R2上ping R3的Loopback接口地址的时候，数据包的三层包头的源地址是路由器R2的接口地址，即为10.0.123.2。

在R3的路由表中，没有到达10.0.123.2/32的路由表项，故该数据包被丢弃了。从这里我们可以看出，当网络类型由P2MP改为P2P以后，R2和R3就学习不到对方的直连接口地址了。当然，这其实不影响R2和R3所连接用户的通信，我们可以使用带源地址的方式来验证连通性。

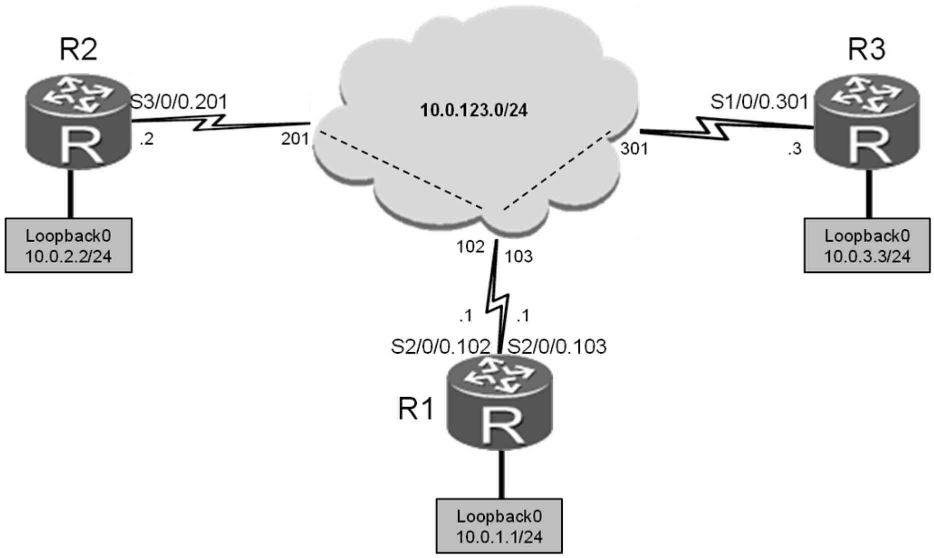
可以看到若使用扩展Ping，将Ping数据包的源地址设为R2的Loopback接口

地址，可以与R3通讯。

```
[R2]ping -c 1 -a 10.0.2.2 10.0.3.3
  PING 10.0.3.3: 56  data bytes, press CTRL_C to break
    Reply from 10.0.3.3: bytes=56 Sequence=1 ttl=254 time=123 ms

  --- 10.0.3.3 ping statistics ---
    1 packet(s) transmitted
    1 packet(s) received
    0.00% packet loss
    round-trip min/avg/max = 123/123/123 ms
```

步骤六.　配置 P2P 类型的 OSPF 网络



在这里我们要重新对地址做规划。如图所示，R1与R2之间使用10.0.12.0/24互联，R1与R3之间使用网段10.0.13.0/24互联。

配置子接口及地址，在配置子接口时，指定接口类型为P2P。

```
[R1]interface s2/0/0
[R1-Serial2/0/0]undo fr map ip 10.0.123.2 102
[R1-Serial2/0/0]undo fr map ip 10.0.123.3 103
[R1-Serial2/0/0]undo ospf network-type
[R1-Serial2/0/0]undo ospf timer hello
[R1-Serial2/0/0]interface Serial 2/0/0.102  p2p
[R1-Serial2/0/0.102]ip address 10.0.12.1 24
[R1-Serial2/0/0.102]ospf network-type p2p
```

```
[R1-Serial2/0/0.102]fr dlci 102
[R1-fr-dlci-Serial2/0/0.102-102]interface Serial 2/0/0.103 p2p
[R1-Serial2/0/0.103]ip address 10.0.13.1 24
[R1-Serial2/0/0.103]ospf network-type p2p
[R1-Serial2/0/0.103]fr dlci 103

[R2]interface Serial 3/0/0
[R2-Serial3/0/0]undo fr map ip 10.0.123.1 201
[R2-Serial3/0/0]undo ip address
[R2-Serial3/0/0]undo ospf network-type
[R2-Serial3/0/0]interface Serial 3/0/0.201 p2p
[R2-Serial3/0/0.201]ip address 10.0.12.2 24
[R2-Serial3/0/0.201]ospf network-type p2p
[R2-Serial3/0/0.201]fr dlci 201

[R3]interface Serial 1/0/0
[R3-Serial1/0/0]undo ip address
[R3-Serial1/0/0]undo fr map ip 10.0.123.1 301
[R3-Serial1/0/0]undo ospf network-type
[R3-Serial1/0/0]interface Serial 1/0/0.301 p2p
[R3-Serial1/0/0.301]ip address 10.0.13.3 24
[R3-Serial1/0/0.301]ospf network-type p2p
[R3-Serial1/0/0.301]fr dlci 301
```

配置完成以后后检查连通性。

```
[R1]ping -c 1 10.0.12.2
  PING 10.0.12.2: 56  data bytes, press CTRL_C to break
    Reply from 10.0.12.2: bytes=56 Sequence=1 ttl=255 time=59 ms

  --- 10.0.12.2 ping statistics ---
    1 packet(s) transmitted
    1 packet(s) received
    0.00% packet loss
    round-trip min/avg/max = 59/59/59 ms

[R1]ping -c 1 10.0.13.3
  PING 10.0.13.3: 56  data bytes, press CTRL_C to break
    Reply from 10.0.13.3: bytes=56 Sequence=1 ttl=255 time=59 ms

  --- 10.0.13.3 ping statistics ---
    1 packet(s) transmitted
    1 packet(s) received
    0.00% packet loss
```

```
   round-trip min/avg/max = 59/59/59 ms
```

在OSPF中修改需发布的网段信息。

```
[R1]ospf 1
[R1-ospf-1]area 0
[R1-ospf-1-area-0.0.0.0]undo network 10.0.123.1 0.0.0.0
[R1-ospf-1-area-0.0.0.0]network 10.0.12.1 0.0.0.0
[R1-ospf-1-area-0.0.0.0]network 10.0.13.1 0.0.0.0

[R2]ospf 1
[R2-ospf-1]area 0
[R2-ospf-1-area-0.0.0.0]undo network 10.0.123.2 0.0.0.0
[R2-ospf-1-area-0.0.0.0]network 10.0.12.2 0.0.0.0

[R3]ospf 1
[R3-ospf-1]area 0
[R3-ospf-1-area-0.0.0.0]undo  network 10.0.123.3 0.0.0.0
[R3-ospf-1-area-0.0.0.0]network  10.0.13.3 0.0.0.0
```

检查OSPF邻居表。

```
[R1]display ospf peer brief

       OSPF Process 1 with Router ID 10.0.123.1
               Peer Statistic Information
 ----------------------------------------------------------------------------
 Area Id          Interface                     Neighbor id      State
 0.0.0.0          Serial2/0/0.102                10.0.2.2         Full
 0.0.0.0          Serial2/0/0.103                10.0.3.3         Full
 ----------------------------------------------------------------------------
```

然后在R1和R2上分别检查OSPF路由表。

```
[R1]display ip routing-table protocol ospf
Route Flags: R - relay, D - download to fib
------------------------------------------------------------------------------
Public routing table : OSPF
       Destinations : 2       Routes : 2

OSPF routing table status : <Active>
       Destinations : 2       Routes : 2

Destination/Mask    Proto   Pre  Cost     Flags NextHop         Interface
```

```
      10.0.2.0/24  OSPF    10   1562       D  10.0.12.2      Serial2/0/0.102
      10.0.3.0/24  OSPF    10   1562       D  10.0.13.3      Serial2/0/0.103

OSPF routing table status : <Inactive>
       Destinations : 0      Routes : 0

[R2]display ip routing-table protocol ospf
Route Flags: R - relay, D - download to fib
------------------------------------------------------------------------------
Public routing table : OSPF
       Destinations : 3      Routes : 3

OSPF routing table status : <Active>
       Destinations : 3      Routes : 3

Destination/Mask    Proto   Pre  Cost     Flags NextHop        Interface

      10.0.1.0/24  OSPF    10   1562       D  10.0.12.1      Serial3/0/0.201
      10.0.3.0/24  OSPF    10   3124       D  10.0.12.1      Serial3/0/0.201
     10.0.13.0/24  OSPF    10   3124       D  10.0.12.1      Serial3/0/0.201

OSPF routing table status : <Inactive>
       Destinations : 0      Routes : 0
```

最后检查网络的连通性。

```
[R2]ping -c 1 10.0.1.1
  PING 10.0.1.1: 56  data bytes, press CTRL_C to break
    Reply from 10.0.1.1: bytes=56 Sequence=1 ttl=255 time=65 ms

  --- 10.0.1.1 ping statistics ---
    1 packet(s) transmitted
    1 packet(s) received
    0.00% packet loss
    round-trip min/avg/max = 65/65/65 ms

[R2]ping -c 1 10.0.3.3
  PING 10.0.3.3: 56  data bytes, press CTRL_C to break
    Reply from 10.0.3.3: bytes=56 Sequence=1 ttl=255 time=95 ms

  --- 10.0.3.3 ping statistics ---
    1 packet(s) transmitted
    1 packet(s) received
```

```
 0.00% packet loss
 round-trip min/avg/max = 95/95/95 ms
```

附加实验：思考并验证

NBMA网络在非全互联的网络上使用时，有什么注意事项？

比较NBMA、P2MP和P2P在使用上的区别。

最终设备配置

```
<R1>display current-configuration
[V200R001C00SPC200]
#
 sysname R1
#
interface Serial2/0/0
 link-protocol fr
 undo fr inarp
#
interface Serial2/0/0.102 p2p
 fr dlci 102
 ip address 10.0.12.1 255.255.255.0
 ospf network-type p2p
#
interface Serial2/0/0.103 p2p
 fr dlci 103
 ip address 10.0.13.1 255.255.255.0
 ospf network-type p2p
#
interface LoopBack0
 ip address 10.0.1.1 255.255.255.0
 ospf network-type broadcast
#
ospf 1 router-id 10.0.123.1
 area 0.0.0.0
  network 10.0.1.1 0.0.0.0
  network 10.0.12.1 0.0.0.0
  network 10.0.13.1 0.0.0.0
#
return
```

```
<R2>display current-configuration
[V200R001C00SPC200]
#
 sysname R2
#
interface Serial3/0/0
 link-protocol fr
 undo fr inarp
#
interface Serial3/0/0.201 p2p
 fr dlci 201
 ip address 10.0.12.2 255.255.255.0
 ospf network-type p2p
#
interface LoopBack0
 ip address 10.0.2.2 255.255.255.0
 ospf network-type broadcast
#
ospf 1 router-id 10.0.2.2
 area 0.0.0.0
  network 10.0.2.2 0.0.0.0
  network 10.0.12.2 0.0.0.0
#
return
```

```
<R3>display current-configuration
[V200R001C00SPC200]
#
 sysname R3
#
interface Serial1/0/0
 link-protocol fr
 fr map ip 10.0.13.1 301 broadcast
 ip address 10.0.13.3 255.255.255.0
 ospf network-type p2p
#
interface LoopBack0
 ip address 10.0.3.3 255.255.255.0
 ospf network-type broadcast
#
ospf 1 router-id 10.0.3.3
 area 0.0.0.0
  network 10.0.3.3 0.0.0.0
```

```
 network 10.0.13.3 0.0.0.0
#
return
```