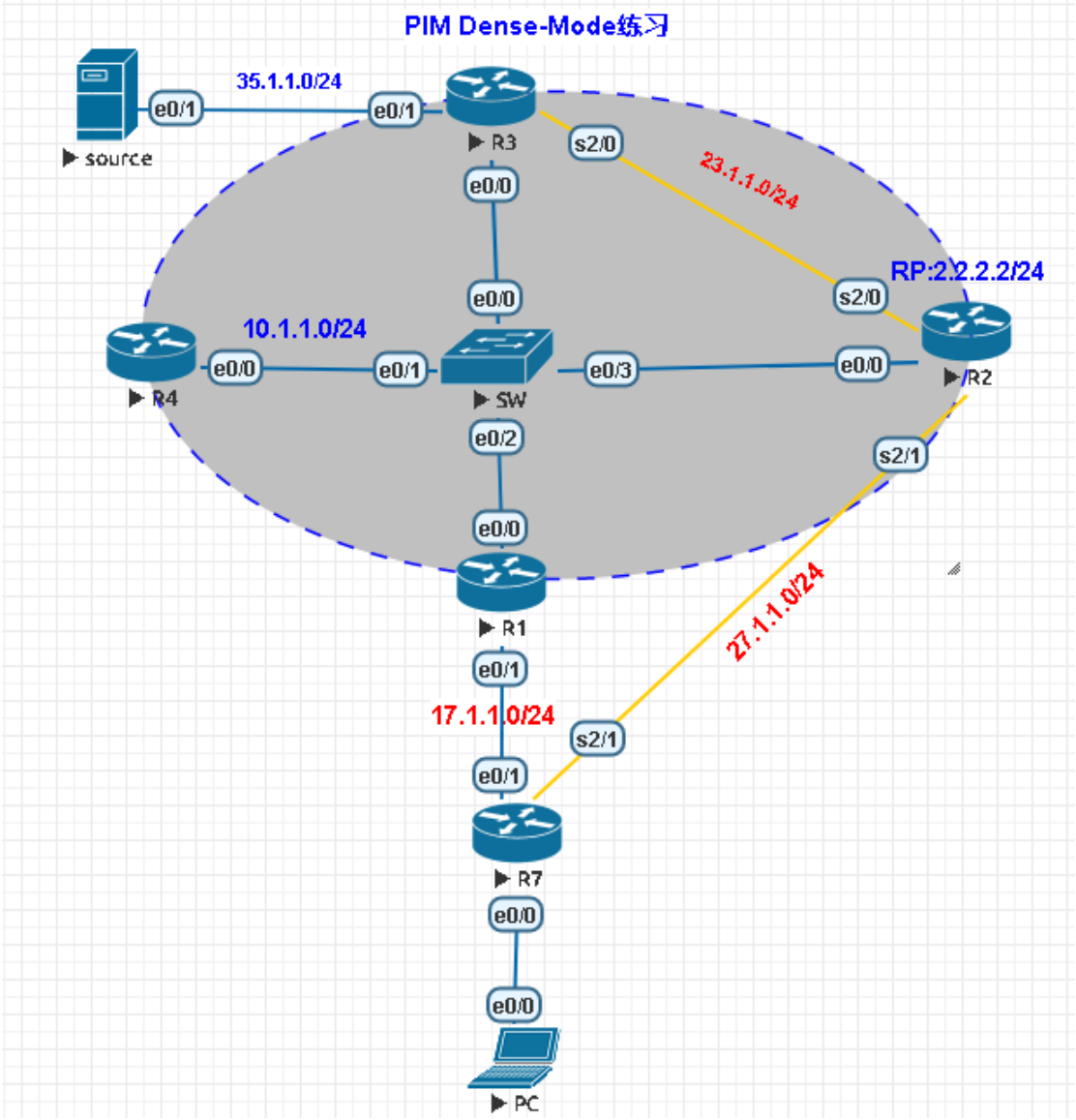
PIM Dense-Mode 练习

一、拓扑



要求：

1.按图中要求配置 PIM Dense-Mode，并且查看相关表项。

二、配置

1.基本 IP 地址配置（省略）。

2.IGP 路由配置，在这里特别注意，必须将 FHR（第一跳路由器）连接信源的网段及 LHR（最后一跳路由器）连接 IGMP 组接收者的网段通告进 IGP 中。

***LHR 连接接收者的网段通告进 IGP 不是必要条件，我们在结尾进行了验证。**

```
R3(config)#router eigrp 90
R3(config-router)#eigrp router-id 3.3.3.3
R3(config-router)#eigrp log-neighbor-changes
R3(config-router)#no auto-summary
R3(config-router)#network 35.1.1.0 0.0.0.255
R3(config-router)#network 23.1.1.3 0.0.0.0
R3(config-router)#network 10.1.1.3 0.0.0.0
```

```
R4(config)#router eigrp 90
R4(config-router)#eigrp router-id 4.4.4.4
R4(config-router)#eigrp log-neighbor-changes
R4(config-router)#no auto-summary
R4(config-router)#network 10.1.1.4 0.0.0.0
```

```
R2(config)#router eigrp 90
R2(config-router)#eigrp router-id 2.2.2.2
R2(config-router)#eigrp log-neighbor-changes
R2(config-router)#no auto-summary
R2(config-router)#network 27.1.1.2 0.0.0.0
R2(config-router)#network 10.1.1.2 0.0.0.0
R2(config-router)#network
*Feb  3 23:16:53.446: %DUAL-5-NBRCHANGE: EIGRP-IPv4 90: Neighbor 10.1.1.4 (Ethernet0/0)
 is up: new adjacency
*Feb  3 23:16:53.446: %DUAL-5-NBRCHANGE: EIGRP-IPv4 90: Neighbor 10.1.1.3 (Ethernet0/0)
 is up: new adjacency
R2(config-router)#network 23.1.1.2 0.0.0.0
```

```
R1(config)#router eigrp 90
R1(config-router)#eigrp router-id 1.1.1.1
R1(config-router)#eigrp log-neighbor-changes
R1(config-router)#no auto-summary
R1(config-router)#network 17.1.1.1 0.0.0.0
R1(config-router)#network 10.1.1.1 0.0.0.0
```

```
R7(config)#router eigrp 90
R7(config-router)#eigrp router-id 7.7.7.7
R7(config-router)#eigrp log-neighbor-changes
R7(config-router)#no auto-summary
R7(config-router)#network 78.1.1.0 0.0.0.255
R7(config-router)#network 27.1.1.7 0.0.0.0
R7(config-router)#network
*Feb  3 23:20:01.039: %DUAL-5-NBRCHANGE: EIGRP-IPv4 90: Neighbor 27.1.1.2 (Serial2/1) i
s up: new adjacency
R7(config-router)#network 17.1.1.7 0.0.0.0
```

3.配置 PIM Dense-Mode

```
R3(config)#ip multicast-routing
R3(config)#interface range e0/0-1
R3(config-if-range)#ip pim dense-mode
R3(config-if-range)#no shutdown
R3(config-if-range)#interface s
*Feb  3 23:22:44.263: %PIM-5-DRCHG: DR change from neighbor 0.0.0.0 to 10.1.1.3 on inte
rface Ethernet0/0
*Feb  3 23:22:44.263: %PIM-5-DRCHG: DR change from neighbor 0.0.0.0 to 35.1.1.3 on inte
rface Ethernet0/1
R3(config-if-range)#interface s2/0
R3(config-if)#ip pim dense-mode
R3(config-if)#no shutdown
```

```
R4(config)#ip multicast-routing
R4(config)#interface e0/0
R4(config-if)#ip pim dense-mode
R4(config-if)#no shutdo
*Feb  3 23:23:37.017: %PIM-5-NBRCHG: neighbor 10.1.1.3 UP on interface Ethernet0/0
R4(config-if)#no shutdown
```

```
R2(config)#ip multicast-routing
R2(config)#interface range e0/0
R2(config-if-range)#ip pim dense-mode
R2(config-if-range)#no shutdow
*Feb  3 23:24:26.082: %PIM-5-NBRCHG: neighbor 10.1.1.4 UP on interface Ethernet0/0
*Feb  3 23:24:26.084: %PIM-5-DRCHG: DR change from neighbor 0.0.0.0 to 10.1.1.4 on interface Ether
net0/0
*Feb  3 23:24:26.084: %PIM-5-NBRCHG: neighbor 10.1.1.3 UP on interface Ethernet0/0
R2(config-if-range)#no shutdown
R2(config-if-range)#interface s2/0
R2(config-if)#ip pim dense-mode
R2(config-if)#no shutdo
*Feb  3 23:24:34.399: %PIM-5-NBRCHG: neighbor 23.1.1.3 UP on interface Serial2/0
R2(config-if)#no shutdown
R2(config-if)#interface s2/1
R2(config-if)#ip pim dense-mode
R2(config-if)#no shutdown
```

```
R1(config)#ip multicast-routing
R1(config)#interface range e0/0-1
R1(config-if-range)#ip pim dense-mode
R1(config-if-range)#no shutdown
```

```
R7(config)#ip multicast-routing
R7(config)#interface e0/1
R7(config-if)#ip pim dense-mode
R7(config-if)#no shutdown
*Feb  3 23:26:07.114: %PIM-5-NBRCHG: neighbor 17.1.1.1 UP on interface Ethernet0/1
*Feb  3 23:26:08.114: %PIM-5-DRCHG: DR change from neighbor 0.0.0.0 to 17.1.1.7 on interface Ether
net0/1
R7(config-if)#no shutdown
R7(config-if)#interface e0/0
R7(config-if)#ip pim dense-mode
R7(config-if)#no shutdown
R7(config-if)#interface
*Feb  3 23:26:21.110: %PIM-5-DRCHG: DR change from neighbor 0.0.0.0 to 78.1.1.7 on interface Ether
net0/0
R7(config-if)#interface s2/1
R7(config-if)#ip pim dense-mode
R7(config-if)#no shutdown
*Feb  3 23:26:28.292: %PIM-5-NBRCHG: neighbor 27.1.1.2 UP on interface Serial2/1
R7(config-if)#no shutdown
```

即在所有的 PIM 路由器上完成了 PIM Dense-Mode 的配置，**特别要强调 FHR 连接到信源的接口必须开启 PIM，LHR 连接接收者的接口亦必须开启 PIM，前者会影响 FHR 的 RFP 校验，后者影响 IGMP 协议的正常运行。**

查看 PIM 邻居如下：

```
R3#show ip pim neighbor
PIM Neighbor Table
Mode: B - Bidir Capable, DR - Designated Router, N - Default DR Priority,
      P - Proxy Capable, S - State Refresh Capable, G - GenID Capable
Neighbor          Interface                Uptime/Expires    Ver   DR
Address                                                            Prio/Mode
10.1.1.1          Ethernet0/0              00:04:01/00:01:39 v2    1 / S P G
10.1.1.2          Ethernet0/0              00:04:57/00:01:39 v2    1 / S P G
10.1.1.4          Ethernet0/0              00:05:46/00:01:40 v2    1 / DR S P G
23.1.1.2          Serial2/0                00:04:49/00:01:21 v2    1 / S P G
R3#
```

可以看到 R3 的所有 PIM 邻居，并且 10.1.1.4 的邻居为 DR。

```
R7#show ip pim neighbor
PIM Neighbor Table
Mode: B - Bidir Capable, DR - Designated Router, N - Default DR Priority,
      P - Proxy Capable, S - State Refresh Capable, G - GenID Capable
Neighbor          Interface                Uptime/Expires    Ver   DR
Address                                                            Prio/Mode
17.1.1.1          Ethernet0/1              00:04:38/00:01:30 v2    1 / S P G
27.1.1.2          Serial2/1                00:04:17/00:01:25 v2    1 / S P G
R7#
```

而 R1 和 R7 之间建立了 PIM 邻居关系，但并没有选择 DR，对比说明：

PIM 邻居在 MA 网段上要选择 DR，而在 P2P 网段上不选 DR。

再查看 IGMP 表，在 R3 和 R7 上查看

```
R3#show ip igmp group
IGMP Connected Group Membership
Group Address    Interface                Uptime    Expires   Last Reporter   Group Accounted
224.0.1.40       Ethernet0/0              00:10:02  00:02:38  10.1.1.2
R3#
```

```
R7#show ip igmp groups
IGMP Connected Group Membership
Group Address    Interface                Uptime    Expires   Last Reporter   Group Accounted
224.0.1.40       Ethernet0/1              00:06:45  00:02:29  17.1.1.7
R7#
```

发现并无 IGMP 表项

4.将 PC 加入到组 224.1.1.1 中

```
PC(config)#interface e0/0
PC(config-if)#ip igmp join-group 224.1.1.1
PC(config-if)#no shutdown
```

再查看 IGMP 表

```
R7#show ip igmp groups
IGMP Connected Group Membership
Group Address    Interface                Uptime    Expires   Last Reporter   Group Accounted
224.1.1.1        Ethernet0/0              00:00:44  00:02:50  78.1.1.8
224.0.1.40       Ethernet0/1              00:09:28  00:02:53  17.1.1.7
R7#
```

```
R3#show ip igmp group
IGMP Connected Group Membership
Group Address    Interface                Uptime    Expires   Last Reporter   Group Accounted
224.0.1.40       Ethernet0/0              00:13:17  00:02:23  10.1.1.4
R3#
```

可以看到 R7 上有 IGMP 表项，而 R3 上仍然没有，这是为什么呢？、

因为 IGMP 协议运行在 LHR 和接收者之间，属于组播架构的第三部分，而 R3、R4、R2、R1 都是属于组播架构的第二部分，它们之间是 PIM 协议，而没有运行 IGMP 协议，故不可能存在 IGMP 表项，我们查看 R1

```
R1#show ip igmp groups
IGMP Connected Group Membership
Group Address    Interface                Uptime    Expires   Last Reporter   Group Accounted
224.0.1.40       Ethernet0/1              00:11:51  00:02:27  17.1.1.7
224.0.1.40       Ethernet0/0              00:12:37  00:02:27  10.1.1.1
R1#
```

明显看出，R1 上亦没有表项。

5.查看 PIM 路由器上的组播表，我们分别查看 R3、R1、R2、R7 的组播路由表

```
R7#show ip mroute
IP Multicast Routing Table
Flags: D - Dense, S - Sparse, B - Bidir Group, s - SSM Group, C - Connected,
       L - Local, P - Pruned, R - RP-bit set, F - Register flag,
       T - SPT-bit set, J - Join SPT, M - MSDP created entry, E - Extranet,
       X - Proxy Join Timer Running, A - Candidate for MSDP Advertisement,
       U - URD, I - Received Source Specific Host Report,
       Z - Multicast Tunnel, z - MDT-data group sender,
       Y - Joined MDT-data group, y - Sending to MDT-data group,
       V - RD & Vector, v - Vector
Outgoing interface flags: H - Hardware switched, A - Assert winner
 Timers: Uptime/Expires
 Interface state: Interface, Next-Hop or VCD, State/Mode

(*, 224.1.1.1), 00:05:09/00:02:22, RP 0.0.0.0, flags: DC
  Incoming interface: Null, RPF nbr 0.0.0.0
  Outgoing interface list:
    Serial2/1, Forward/Dense, 00:05:09/stopped
    Ethernet0/0, Forward/Dense, 00:05:09/stopped
    Ethernet0/1, Forward/Dense, 00:05:09/stopped
```

```
R1#show ip mroute
IP Multicast Routing Table
Flags: D - Dense, S - Sparse, B - Bidir Group, s - SSM Group, C - Connected,
       L - Local, P - Pruned, R - RP-bit set, F - Register flag,
       T - SPT-bit set, J - Join SPT, M - MSDP created entry, E - Extranet,
       X - Proxy Join Timer Running, A - Candidate for MSDP Advertisement,
       U - URD, I - Received Source Specific Host Report,
       Z - Multicast Tunnel, z - MDT-data group sender,
       Y - Joined MDT-data group, y - Sending to MDT-data group,
       V - RD & Vector, v - Vector
Outgoing interface flags: H - Hardware switched, A - Assert winner
 Timers: Uptime/Expires
 Interface state: Interface, Next-Hop or VCD, State/Mode

(*, 224.0.1.40), 00:16:20/00:02:44, RP 0.0.0.0, flags: DCL
  Incoming interface: Null, RPF nbr 0.0.0.0
  Outgoing interface list:
    Ethernet0/1, Forward/Dense, 00:15:35/stopped
    Ethernet0/0, Forward/Dense, 00:16:20/stopped

R1#
```

```
R2#show ip mroute
IP Multicast Routing Table
Flags: D - Dense, S - Sparse, B - Bidir Group, s - SSM Group, C - Connected,
       L - Local, P - Pruned, R - RP-bit set, F - Register flag,
       T - SPT-bit set, J - Join SPT, M - MSDP created entry, E - Extranet,
       X - Proxy Join Timer Running, A - Candidate for MSDP Advertisement,
       U - URD, I - Received Source Specific Host Report,
       Z - Multicast Tunnel, z - MDT-data group sender,
       Y - Joined MDT-data group, y - Sending to MDT-data group,
       V - RD & Vector, v - Vector
Outgoing interface flags: H - Hardware switched, A - Assert winner
 Timers: Uptime/Expires
 Interface state: Interface, Next-Hop or VCD, State/Mode

(*, 224.0.1.40), 00:38:31/00:02:25, RP 0.0.0.0, flags: DCL
  Incoming interface: Null, RPF nbr 0.0.0.0
  Outgoing interface list:
    Serial2/1, Forward/Dense, 00:36:29/stopped
    Serial2/0, Forward/Dense, 00:38:23/stopped
    Ethernet0/0, Forward/Dense, 00:38:31/stopped

R2#
```

```
R3#show ip mroute
IP Multicast Routing Table
Flags: D - Dense, S - Sparse, B - Bidir Group, s - SSM Group, C - Connected,
       L - Local, P - Pruned, R - RP-bit set, F - Register flag,
       T - SPT-bit set, J - Join SPT, M - MSDP created entry, E - Extranet,
       X - Proxy Join Timer Running, A - Candidate for MSDP Advertisement,
       U - URD, I - Received Source Specific Host Report,
       Z - Multicast Tunnel, z - MDT-data group sender,
       Y - Joined MDT-data group, y - Sending to MDT-data group,
       V - RD & Vector, v - Vector
Outgoing interface flags: H - Hardware switched, A - Assert winner
 Timers: Uptime/Expires
 Interface state: Interface, Next-Hop or VCD, State/Mode

(*, 224.0.1.40), 00:41:03/00:02:37, RP 0.0.0.0, flags: DCL
  Incoming interface: Null, RPF nbr 0.0.0.0
  Outgoing interface list:
    Serial2/0, Forward/Dense, 00:39:11/stopped
    Ethernet0/0, Forward/Dense, 00:41:03/stopped

R3#
```

可以看到 R7 上有一个(*.224.1.1.1)的表项，而 R1、R2、R3 上却没有，这个(*.224.1.1.1)是什么呢？为什么 R7 上有，而 R1、R2、R3 上没有呢？分析如下:

PC 加入组 224.1.1.1 时，会发出一个 IGMPV2 的 Report 报文，这样在 R7 的 IGMP 表中会产生记录，同时在 R7 的组播表中产生(*.224.1.1.1)，这个表示了，在 R7 的下游有隶属 224.1.1.1 的成员，但其并不知道信源在哪里，所以只能表示为(*.224.1.1.1)形式。

6.信源 Server 发送去往 224.1.1.1 的组播流量，再查看相关表项

```
Source#ping 224.1.1.1 repeat 100000
Type escape sequence to abort.
Sending 100000, 100-byte ICMP Echos to 224.1.1.1, timeout is 2 seconds:

Reply to request 0 from 78.1.1.8, 71 ms
Reply to request 1 from 78.1.1.8, 4 ms
```

分别查看 R7、R2、R1、R4、R3 的表项

```
R7#show ip mroute
IP Multicast Routing Table
Flags: D - Dense, S - Sparse, B - Bidir Group, s - SSM Group, C - Connected,
       L - Local, P - Pruned, R - RP-bit set, F - Register flag,
       T - SPT-bit set, J - Join SPT, M - MSDP created entry, E - Extranet,
       X - Proxy Join Timer Running, A - Candidate for MSDP Advertisement,
       U - URD, I - Received Source Specific Host Report,
       Z - Multicast Tunnel, z - MDT-data group sender,
       Y - Joined MDT-data group, y - Sending to MDT-data group,
       V - RD & Vector, v - Vector
Outgoing interface flags: H - Hardware switched, A - Assert winner
 Timers: Uptime/Expires
 Interface state: Interface, Next-Hop or VCD, State/Mode

(*, 224.1.1.1), 00:34:16/stopped, RP 0.0.0.0, flags: DC
  Incoming interface: Null, RPF nbr 0.0.0.0
  Outgoing interface list:
    Serial2/1, Forward/Dense, 00:34:16/stopped
    Ethernet0/0, Forward/Dense, 00:34:16/stopped
    Ethernet0/1, Forward/Dense, 00:34:16/stopped

(35.1.1.5, 224.1.1.1), 00:00:41/00:02:18, flags: T
  Incoming interface: Ethernet0/1, RPF nbr 17.1.1.1
  Outgoing interface list:
    Ethernet0/0, Forward/Dense, 00:00:41/stopped
    Serial2/1, Prune/Dense, 00:00:40/00:02:18
```

可以看到 R7 的组播表中产生了(35.1.1.5,224.1.1.1)的记录，同时其 RPF 接口为 E0/1，连接在该接口上的邻居（又叫 RPF 邻居）为 17.1.1.1。

来自 224.1.1.1 的组播流量由 E0/1 进入 R7，其有两个出接口，分别为 E0/0、S2/1，其串 E0/0 的状态为 Forward，而 S2/1 的状态为 Prune，即处于修剪状态，不能转发组播流量。

```
R1#show ip mroute
IP Multicast Routing Table
Flags: D - Dense, S - Sparse, B - Bidir Group, s - SSM Group, C - Connected,
       L - Local, P - Pruned, R - RP-bit set, F - Register flag,
       T - SPT-bit set, J - Join SPT, M - MSDP created entry, E - Extranet,
       X - Proxy Join Timer Running, A - Candidate for MSDP Advertisement,
       U - URD, I - Received Source Specific Host Report,
       Z - Multicast Tunnel, z - MDT-data group sender,
       Y - Joined MDT-data group, y - Sending to MDT-data group,
       V - RD & Vector, v - Vector
Outgoing interface flags: H - Hardware switched, A - Assert winner
 Timers: Uptime/Expires
 Interface state: Interface, Next-Hop or VCD, State/Mode

(*, 224.1.1.1), 00:04:46/stopped, RP 0.0.0.0, flags: D
  Incoming interface: Null, RPF nbr 0.0.0.0
  Outgoing interface list:
    Ethernet0/1, Forward/Dense, 00:04:46/stopped
    Ethernet0/0, Forward/Dense, 00:04:46/stopped

(35.1.1.5, 224.1.1.1), 00:04:46/00:02:12, flags: T
  Incoming interface: Ethernet0/0, RPF nbr 10.1.1.3
  Outgoing interface list:
    Ethernet0/1, Forward/Dense, 00:04:46/stopped
```

R1 同样的解释，在这里不多叙述。

```
R2#show ip mroute
IP Multicast Routing Table
Flags: D - Dense, S - Sparse, B - Bidir Group, s - SSM Group, C - Connected,
       L - Local, P - Pruned, R - RP-bit set, F - Register flag,
       T - SPT-bit set, J - Join SPT, M - MSDP created entry, E - Extranet,
       X - Proxy Join Timer Running, A - Candidate for MSDP Advertisement,
       U - URD, I - Received Source Specific Host Report,
       Z - Multicast Tunnel, z - MDT-data group sender,
       Y - Joined MDT-data group, y - Sending to MDT-data group,
       V - RD & Vector, v - Vector
Outgoing interface flags: H - Hardware switched, A - Assert winner
 Timers: Uptime/Expires
 Interface state: Interface, Next-Hop or VCD, State/Mode

(*, 224.1.1.1), 00:05:41/stopped, RP 0.0.0.0, flags: D
  Incoming interface: Null, RPF nbr 0.0.0.0
  Outgoing interface list:
    Serial2/1, Forward/Dense, 00:05:41/stopped
    Serial2/0, Forward/Dense, 00:05:41/stopped
    Ethernet0/0, Forward/Dense, 00:05:41/stopped

(35.1.1.5, 224.1.1.1), 00:05:41/00:01:04, flags: PT
  Incoming interface: Ethernet0/0, RPF nbr 10.1.1.3
  Outgoing interface list:
    Serial2/0, Prune/Dense, 00:02:41/00:00:18
    Serial2/1, Prune/Dense, 00:02:41/00:00:18, A
```

而 R2 上的 RPF 接口和 RPF 邻居分别为 E0/0 和 R3，注意 Flags 后有 P 标志，代表该路由器正被修剪，即 R3 会暂停给 R2 转发 224.1.1.1 的组播流量，这是为什么呢？分析如下：
R1、R2 都和 R7 相连，都会向 R7 转发组播流量，并且这些流量是完全相同的，这样会产生重复报文，所以 R7 会进行比较，分别比较经过 R1、R2 到达信源时的单播路由的管理距离、度量值和接口 IP 地址大小，故从下图

```
R7#show ip eigrp topology
EIGRP-IPv4 Topology Table for AS(90)/ID(7.7.7.7)
Codes: P - Passive, A - Active, U - Update, Q - Query, R - Reply,
       r - reply Status, s - sia Status

P 35.1.1.0/24, 1 successors, FD is 332800
        via 17.1.1.1 (332800/307200), Ethernet0/1
        via 27.1.1.2 (2221056/307200), Serial2/1
P 27.1.1.0/24, 1 successors, FD is 2169856
        via Connected, Serial2/1
P 78.1.1.0/24, 1 successors, FD is 281600
        via Connected, Ethernet0/0
P 23.1.1.0/24, 1 successors, FD is 2221056
        via 17.1.1.1 (2221056/2195456), Ethernet0/1
        via 27.1.1.2 (2681856/2169856), Serial2/1
P 17.1.1.0/24, 1 successors, FD is 281600
        via Connected, Ethernet0/1
P 10.1.1.0/24, 1 successors, FD is 307200
        via 17.1.1.1 (307200/281600), Ethernet0/1
        via 27.1.1.2 (2195456/281600), Serial2/1
```

可看出，R7 经 R1、R2 访问信源时，其度量值分别为 32800、2221056，故 R7 经过 R1 访问信源的路径胜出，亦即 R1 的 E0/1 在 Assert 比较中胜出，故 R2 的 S2/1 接口失败，即 R2 的 S2/1 接口不会向 R7 转发组播流量。

而 R2 的 s2/0 接口在进行 RPF 校验时，明显失败，故该接口也成为出接口，其会把从自己的 e0/0 口收到的组播报文经 S2/0 转发给 R3，而 R3 又会进行 RPF 校验，所以 R2 的 S2/0 被 Prune 掉。

```
R4#show ip mroute
IP Multicast Routing Table
Flags: D - Dense, S - Sparse, B - Bidir Group, s - SSM Group, C - Connected,
       L - Local, P - Pruned, R - RP-bit set, F - Register flag,
       T - SPT-bit set, J - Join SPT, M - MSDP created entry, E - Extranet,
       X - Proxy Join Timer Running, A - Candidate for MSDP Advertisement,
       U - URD, I - Received Source Specific Host Report,
       Z - Multicast Tunnel, z - MDT-data group sender,
       Y - Joined MDT-data group, y - Sending to MDT-data group,
       V - RD & Vector, v - Vector
Outgoing interface flags: H - Hardware switched, A - Assert winner
 Timers: Uptime/Expires
 Interface state: Interface, Next-Hop or VCD, State/Mode

(*, 224.1.1.1), 01:32:22/stopped, RP 0.0.0.0, flags: D
  Incoming interface: Null, RPF nbr 0.0.0.0
  Outgoing interface list:
    Ethernet0/0, Forward/Dense, 01:32:22/stopped

(35.1.1.5, 224.1.1.1), 01:32:22/00:02:19, flags: PT
  Incoming interface: Ethernet0/0, RPF nbr 10.1.1.3
  Outgoing interface list: Null

(*, 224.0.1.40), 02:17:12/00:02:35, RP 0.0.0.0, flags: DCL
  Incoming interface: Null, RPF nbr 0.0.0.0
  Outgoing interface list:
    Ethernet0/0, Forward/Dense, 02:17:12/stopped
```

```
R3#show ip mroute
IP Multicast Routing Table
Flags: D - Dense, S - Sparse, B - Bidir Group, s - SSM Group, C - Connected,
       L - Local, P - Pruned, R - RP-bit set, F - Register flag,
       T - SPT-bit set, J - Join SPT, M - MSDP created entry, E - Extranet,
       X - Proxy Join Timer Running, A - Candidate for MSDP Advertisement,
       U - URD, I - Received Source Specific Host Report,
       Z - Multicast Tunnel, z - MDT-data group sender,
       Y - Joined MDT-data group, y - Sending to MDT-data group,
       V - RD & Vector, v - Vector
Outgoing interface flags: H - Hardware switched, A - Assert winner
 Timers: Uptime/Expires
 Interface state: Interface, Next-Hop or VCD, State/Mode

(*, 224.1.1.1), 01:33:27/stopped, RP 0.0.0.0, flags: D
  Incoming interface: Null, RPF nbr 0.0.0.0
  Outgoing interface list:
    Serial2/0, Forward/Dense, 01:33:27/stopped
    Ethernet0/0, Forward/Dense, 01:33:27/stopped

(35.1.1.5, 224.1.1.1), 01:33:27/00:01:14, flags: T
  Incoming interface: Ethernet0/1, RPF nbr 0.0.0.0
  Outgoing interface list:
    Ethernet0/0, Forward/Dense, 01:33:27/stopped
    Serial2/0, Prune/Dense, 00:02:47/00:00:14, A

(*, 224.0.1.40), 02:19:12/00:02:30, RP 0.0.0.0, flags: DCL
  Incoming interface: Null, RPF nbr 0.0.0.0
  Outgoing interface list:
    Serial2/0, Forward/Dense, 02:17:19/stopped
    Ethernet0/0, Forward/Dense, 02:19:12/stopped
```

同样分析 R3、R4，可以得出在该拓扑中，SPT 的路径为

Source——>e0/1——>R3——>e0/0——>R1——>e0/1——>R7——>e0/0——>PC。

现在提出新的问题：

如果我们想将 SPT 的路径改为：

Source——>e0/1——>R3——>s2/0——>R2——>s2/1——>R7——>e0/0——>PC，

那该怎么办呢？

通过分析，要想让 SPT 改成上面的形式，则必须在 R7 上修改 RPF 接口，即让 R7 的 s2/1 成为 RPF 接口，通过 RPF 接口比较的原则，①路由度量值②接口 IP 地址，可以通过修改路由度量值的方法或者写静态组播路由的方法进行修改，现演示如下：

①写静态组播路由

在 R7 上写静态组播路由

```
R7(config)#ip mroute 35.1.1.5 255.255.255.255 s2/1 10
R7(config)#do show ip mroute
IP Multicast Routing Table
Flags: D - Dense, S - Sparse, B - Bidir Group, s - SSM Group, C - Connected,
       L - Local, P - Pruned, R - RP-bit set, F - Register flag,
       T - SPT-bit set, J - Join SPT, M - MSDP created entry, E - Extranet,
       X - Proxy Join Timer Running, A - Candidate for MSDP Advertisement,
       U - URD, I - Received Source Specific Host Report,
       Z - Multicast Tunnel, z - MDT-data group sender,
       Y - Joined MDT-data group, y - Sending to MDT-data group,
       V - RD & Vector, v - Vector
Outgoing interface flags: H - Hardware switched, A - Assert winner
 Timers: Uptime/Expires
 Interface state: Interface, Next-Hop or VCD, State/Mode

(*, 224.1.1.1), 02:17:56/stopped, RP 0.0.0.0, flags: DC
  Incoming interface: Null, RPF nbr 0.0.0.0
  Outgoing interface list:
    Serial2/1, Forward/Dense, 02:17:56/stopped
    Ethernet0/0, Forward/Dense, 02:17:56/stopped
    Ethernet0/1, Forward/Dense, 02:17:56/stopped

(35.1.1.5, 224.1.1.1), 01:44:20/00:03:01, flags: T
  Incoming interface: Serial2/1, RPF nbr 27.1.1.2, Mroute
  Outgoing interface list:
    Ethernet0/1, Prune/Dense, 00:00:02/00:02:59, A
    Ethernet0/0, Forward/Dense, 01:44:20/stopped
```

此时可以看到 R7 的 RPF 接口变成了 S2/1，即 R7 从 R2 处收到组播流量，而不接收 R1 的组播流量，再查看 R2 的组播表

```
R2#show ip mroute
IP Multicast Routing Table
Flags: D - Dense, S - Sparse, B - Bidir Group, s - SSM Group, C - Connected,
       L - Local, P - Pruned, R - RP-bit set, F - Register flag,
       T - SPT-bit set, J - Join SPT, M - MSDP created entry, E - Extranet,
       X - Proxy Join Timer Running, A - Candidate for MSDP Advertisement,
       U - URD, I - Received Source Specific Host Report,
       Z - Multicast Tunnel, z - MDT-data group sender,
       Y - Joined MDT-data group, y - Sending to MDT-data group,
       V - RD & Vector, v - Vector
Outgoing interface flags: H - Hardware switched, A - Assert winner
 Timers: Uptime/Expires
 Interface state: Interface, Next-Hop or VCD, State/Mode

(*, 224.1.1.1), 01:46:41/stopped, RP 0.0.0.0, flags: D
  Incoming interface: Null, RPF nbr 0.0.0.0
  Outgoing interface list:
    Serial2/1, Forward/Dense, 01:46:41/stopped
    Serial2/0, Forward/Dense, 01:46:41/stopped
    Ethernet0/0, Forward/Dense, 01:46:41/stopped

(35.1.1.5, 224.1.1.1), 01:46:41/00:01:54, flags: T
  Incoming interface: Ethernet0/0, RPF nbr 10.1.1.3
  Outgoing interface list:
    Serial2/0, Prune/Dense, 00:00:56/00:02:03
    Serial2/1, Forward/Dense, 00:02:25/stopped, A
```

可以看到 R2 的 RPF 接口为 e0/0，并不是 S2/0，所以在 R2 上再写组播静态路由

```
R2(config)#
R2(config)#ip mroute 35.1.1.5 255.255.255.255 s2/0 10
R2(config)#do show ip mroute
IP Multicast Routing Table
Flags: D - Dense, S - Sparse, B - Bidir Group, s - SSM Group, C - Connected,
       L - Local, P - Pruned, R - RP-bit set, F - Register flag,
       T - SPT-bit set, J - Join SPT, M - MSDP created entry, E - Extranet,
       X - Proxy Join Timer Running, A - Candidate for MSDP Advertisement,
       U - URD, I - Received Source Specific Host Report,
       Z - Multicast Tunnel, z - MDT-data group sender,
       Y - Joined MDT-data group, y - Sending to MDT-data group,
       V - RD & Vector, v - Vector
Outgoing interface flags: H - Hardware switched, A - Assert winner
 Timers: Uptime/Expires
 Interface state: Interface, Next-Hop or VCD, State/Mode

(*, 224.1.1.1), 01:49:31/stopped, RP 0.0.0.0, flags: D
  Incoming interface: Null, RPF nbr 0.0.0.0
  Outgoing interface list:
    Serial2/1, Forward/Dense, 01:49:31/stopped
    Serial2/0, Forward/Dense, 01:49:31/stopped
    Ethernet0/0, Forward/Dense, 01:49:31/stopped

(35.1.1.5, 224.1.1.1), 01:49:31/00:01:04, flags: T
  Incoming interface: Serial2/0, RPF nbr 23.1.1.3, Mroute
  Outgoing interface list:
    Ethernet0/0, Prune/Dense, 00:00:01/00:02:58
    Serial2/1, Forward/Dense, 00:05:14/stopped, A
```

可以看到此时的 SPT 变为：

Source——>e0/1——>R3——>s2/0——>R2——>s2/1——>R7——>e0/0——>PC。

接着使用修改路由度量值的方法修改 SPT。

②利用路由度量值修改 SPT

利用路由度量值时，由于 R2、R7 上都要修改 RPF 接口，而一旦在 R2 上利用度量值修改的方法选择了 SPT，势必影响到 R7 上的 RPF 接口的选择，故在使用路量值修改的方法选择 RPF 接口时，应先修改 R2，再修改 R7，

当然在修改度量值前，应当先把 R2、R7 上的组播路由去掉

```
R7(config)#no ip mroute 35.1.1.5 255.255.255.255 s2/1 10
R7(config)#
```

```
R2(config)#no ip mroute 35.1.1.5 255.255.255.255 s2/0 10
R2(config)#
```

然后修改 R2 上的度量值，

```
R2#show ip eigrp topology
EIGRP-IPv4 Topology Table for AS(90)/ID(2.2.2.2)
Codes: P - Passive, A - Active, U - Update, Q - Query, R - Reply,
       r - reply Status, s - sia Status

P 35.1.1.0/24, 1 successors, FD is 307200
       via 10.1.1.3 (307200/281600), Ethernet0/0
       via 23.1.1.3 (2195456/281600), Serial2/0
P 27.1.1.0/24, 1 successors, FD is 2169856
```

通过比较，可以看出，当 R2 从 e0/0 学习到去往 35.1.1.0/24 的路由时，需要将其度量值增大，增大值>2195456-307200=1888256，现在我们将该值取为 1900000，

```
R2(config)#access-list 35 permit 35.1.1.0 0.0.0.255
R2(config)#router eigrp 90
R2(config-router)#offset-list 35 in 1900000 e0/0
R2(config-router)#exit
```

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

Gateway of last resort is not set

      17.0.0.0/24 is subnetted, 1 subnets
D        17.1.1.0 [90/307200] via 10.1.1.1, 00:00:24, Ethernet0/0
      35.0.0.0/24 is subnetted, 1 subnets
D        35.1.1.0 [90/2195456] via 23.1.1.3, 00:00:24, Serial2/0
      78.0.0.0/24 is subnetted, 1 subnets
D        78.1.1.0 [90/332800] via 10.1.1.1, 00:00:24, Ethernet0/0
R2#
```

```
R2#show ip mroute
IP Multicast Routing Table
Flags: D - Dense, S - Sparse, B - Bidir Group, s - SSM Group, C - Connected,
       L - Local, P - Pruned, R - RP-bit set, F - Register flag,
       T - SPT-bit set, J - Join SPT, M - MSDP created entry, E - Extranet,
       X - Proxy Join Timer Running, A - Candidate for MSDP Advertisement,
       U - URD, I - Received Source Specific Host Report,
       Z - Multicast Tunnel, z - MDT-data group sender,
       Y - Joined MDT-data group, y - Sending to MDT-data group,
       V - RD & Vector, v - Vector
Outgoing interface flags: H - Hardware switched, A - Assert winner
 Timers: Uptime/Expires
 Interface state: Interface, Next-Hop or VCD, State/Mode

(*, 224.1.1.1), 02:35:32/stopped, RP 0.0.0.0, flags: D
  Incoming interface: Null, RPF nbr 0.0.0.0
  Outgoing interface list:
    Serial2/1, Forward/Dense, 02:35:32/stopped
    Serial2/0, Forward/Dense, 02:35:32/stopped
    Ethernet0/0, Forward/Dense, 02:35:32/stopped

(35.1.1.5, 224.1.1.1), 02:35:32/00:01:56, flags: T
  Incoming interface: Serial2/0, RPF nbr 23.1.1.3
  Outgoing interface list:
    Ethernet0/0, Prune/Dense, 00:02:15/00:00:44
    Serial2/1, Forward/Dense, 00:00:03/stopped
```

可以看到此时 R2 的 RPF 接口已经变为 S2/0，同样的方法修改 R7 的 RPF

```
R7#show ip eigrp topology 35.1.1.0 255.255.255.0
EIGRP-IPv4 Topology Entry for AS(90)/ID(7.7.7.7) for 35.1.1.0/24
  State is Passive, Query origin flag is 1, 1 Successor(s), FD is 332800
  Descriptor Blocks:
  17.1.1.1 (Ethernet0/1), from 17.1.1.1, Send flag is 0x0
      Composite metric is (332800/307200), route is Internal
      Vector metric:
        Minimum bandwidth is 10000 Kbit
        Total delay is 3000 microseconds
        Reliability is 255/255
        Load is 1/255
        Minimum MTU is 1500
        Hop count is 2
        Originating router is 3.3.3.3
  27.1.1.2 (Serial2/1), from 27.1.1.2, Send flag is 0x0
      Composite metric is (2707456/2195456), route is Internal
      Vector metric:
        Minimum bandwidth is 1544 Kbit
        Total delay is 41000 microseconds
        Reliability is 255/255
        Load is 1/255
        Minimum MTU is 1500
        Hop count is 2
        Originating router is 3.3.3.3
```

可以看出来，R7 经过 R1 和 R2 访问信源时的度量值分别为 332800、2707456，那么必须将 R7 从 R1 学到的去往 35.1.1.0/24 的路由的度量值增大，并且要>2707456-332800=2374656，现我们将该值取为 2400000，

```
R7(config)#access-list 35 permit 35.1.1.0 0.0.0.255
R7(config)#router eigrp 90
R7(config-router)#offset-list 35 in 2400000 e0/1
R7(config-router)#exit
```

```
R7#show ip mroute
IP Multicast Routing Table
Flags: D - Dense, S - Sparse, B - Bidir Group, s - SSM Group, C - Connected,
       L - Local, P - Pruned, R - RP-bit set, F - Register flag,
       T - SPT-bit set, J - Join SPT, M - MSDP created entry, E - Extranet,
       X - Proxy Join Timer Running, A - Candidate for MSDP Advertisement,
       U - URD, I - Received Source Specific Host Report,
       Z - Multicast Tunnel, z - MDT-data group sender,
       Y - Joined MDT-data group, y - Sending to MDT-data group,
       V - RD & Vector, v - Vector
Outgoing interface flags: H - Hardware switched, A - Assert winner
 Timers: Uptime/Expires
 Interface state: Interface, Next-Hop or VCD, State/Mode

(*, 224.1.1.1), 03:40:14/stopped, RP 0.0.0.0, flags: DC
  Incoming interface: Null, RPF nbr 0.0.0.0
  Outgoing interface list:
    Serial2/1, Forward/Dense, 03:40:14/stopped
    Ethernet0/0, Forward/Dense, 03:40:14/stopped
    Ethernet0/1, Forward/Dense, 03:40:14/stopped

(35.1.1.5, 224.1.1.1), 03:06:39/00:01:44, flags: T
  Incoming interface: Serial2/1, RPF nbr 27.1.1.2
  Outgoing interface list:
    Ethernet0/1, Prune/Dense, 00:00:05/00:02:54
    Ethernet0/0, Forward/Dense, 03:06:39/stopped
```

```
R7#show ip route eigrp
Codes: L - local, C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route, H - NHRP, l - LISP
       + - replicated route, % - next hop override

Gateway of last resort is not set

      10.0.0.0/24 is subnetted, 1 subnets
D        10.1.1.0 [90/307200] via 17.1.1.1, 04:13:38, Ethernet0/1
      23.0.0.0/24 is subnetted, 1 subnets
D        23.1.1.0 [90/2221056] via 17.1.1.1, 04:13:38, Ethernet0/1
      35.0.0.0/24 is subnetted, 1 subnets
D        35.1.1.0 [90/2707456] via 27.1.1.2, 00:18:47, Serial2/1
R7#
```

```
R7#show ip eigrp topology
EIGRP-IPv4 Topology Table for AS(90)/ID(7.7.7.7)
Codes: P - Passive, A - Active, U - Update, Q - Query, R - Reply,
       r - reply Status, s - sia Status

P 35.1.1.0/24, 1 successors, FD is 2707456
        via 27.1.1.2 (2707456/2195456), Serial2/1
        via 17.1.1.1 (2732800/2707200), Ethernet0/1
P 27.1.1.0/24, 1 successors, FD is 2169856
        via Connected, Serial2/1
P 78.1.1.0/24, 1 successors, FD is 281600
        via Connected, Ethernet0/0
P 23.1.1.0/24, 1 successors, FD is 2221056
        via 17.1.1.1 (2221056/2195456), Ethernet0/1
        via 27.1.1.2 (2681856/2169856), Serial2/1
P 17.1.1.0/24, 1 successors, FD is 281600
        via Connected, Ethernet0/1
P 10.1.1.0/24, 1 successors, FD is 307200
        via 17.1.1.1 (307200/281600), Ethernet0/1
        via 27.1.1.2 (2195456/281600), Serial2/1

R7#
```

此时可以看到 STP 的路径已经达到了要求。

最后讨论，LHR 上是否要将连接接收者的网段通告进 IGP，我们在 R7 上将 78.1.1.0/24 网段从 Eigrp 通告中取掉，

```
R7(config)#router eigrp 90
R7(config-router)#no network 78.1.1.0 0.0.0.255
R7(config-router)#exit
R7(config)#end
```

再从 PC 访问信源，看能否访问

```
PC#ping 35.1.1.5
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 35.1.1.5, timeout is 2 seconds:
.....
Success rate is 0 percent (0/5)
PC#
```

再在信源上下发组播流量

```
Source#ping 224.1.1.1 repeat 100000
Type escape sequence to abort.
Sending 100000, 100-byte ICMP Echos to 224.1.1.1, timeout is 2 seconds:

Reply to request 0 from 78.1.1.8, 20 ms
Reply to request 1 from 78.1.1.8, 21 ms
Reply to request 2 from 78.1.1.8, 23 ms
Reply to request 3 from 78.1.1.8, 20 ms
```

可以看到，组播流量仍然可以被组 224.1.1.1 的成员收到，这也验让了 PIM 路由器在 Dense-Mode 中，收到组播流量并完成 RPF 验证后，会直接泛洪给其 PIM 邻居和所有的 IGMP 接收者，采用推模型的工作方式进行流量转发的。