**华为认证系列教程**

HCIP-IERS

部署企业级路由交换网络

实验指导书



华为技术有限公司

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**实验指导书**

**第2.5版本**

华为认证体系介绍

华为认证是华为凭借多年信息通信技术人才培养经验及对行业发展的深刻理解，基于ICT产业链人才职业发展生命周期，以学院化的职业技术认证为指引，搭载华为“云－管－端”融合技术，推出覆盖IP、IT、CT技术领域的认证体系，是业界唯一的ICT全技术领域认证体系。

基于IP、IT、CT技术，华为公司提供了工程师、资深工程师和专家三类技术认证等级，为ICT从业者提供了层次化的培训认证。华为认证包括10个领域，12个技术方向的认证，是业界唯一覆盖ICT全技术领域的认证体系。

HCIA是对企业网络初级知识和技能的认证。证明您具备配置和维护小型企业网络的能力。HCIA认证考查工程师协助设计、部署小型企业网络和基本网络运维的能力。目的是考察企业网络工程师使用华为网络设备搭建小型企业路由交换网络的能力，使之能承载基本的语音、无线、云、安全和存储等网络应用，满足企业对网络的使用需求。 HCIA定位于企业网络技术领域具备初级知识和技能水平的专业人士。侧重于对初级企业网络技术的考察和认证。具备HCIA证书的工程师是公认的具备小型企业网络通用技术和基本设计能力的专业人士。

HCIP-R&S是对企业网络高级知识和技能的认证。目的是帮助企业网络工程师使用华为网络设备搭建完整的中小型企业网络，并支撑企业所需的语音、无线、云、安全和存储等应用全面地集成到网络之中，满足企业各种应用对网络的使用需求，并提供较高的安全性、可用性和可靠性。HCIP-R&S定位于企业网络技术领域具备高级知识和技能水平的专业人士。侧重于对中小型企业网络技术的考察和认证。具备HCIP-R&S证书的工程师是公认的具备中小型企业网络构建和管理能力的专业人士。

HCIE-R&S是对企业网络专家级知识和技能的认证。目的是帮助企业网络高级工程师搭建完整的大型复杂企业网络，支撑企业所需的语音、无线、云、安全和存储等应用全面集成到网络之中，满足企业各种应用对网络的使用需求。同时能够提供完整的故障排除能力，可根据企业和网络技术发展来规划企业网络，并提高安全性、可用性和可靠性。HCIE-R&S定位于企业网络技术领域中具备专家知识和技能水平的专业人士。侧重于对大型复杂企业网络技术的考察和认证。具备HCIE-R&S证书的工程师是公认的具备大型复杂企业网络构建、优化和管理能力的专业人士。

华为认证协助您打开行业之窗，开启改变之门，屹立在ICT世界的潮头浪尖！

**前言**

**简介**

本书为HCIP-IERS认证培训教程，适用于准备参加HCIP-IERS考试的学员或者希望系统掌握通用路由协议原理以及在华为通用路由平台VRP上的实现的读者。

**内容描述**

Module 1、2、3分别系统而详尽地介绍内部网关协议OSPF、IS-IS以及外部网关协议BGP的工作原理以及在VRP上的配置和实现。帮助读者全面深入地掌握IPv4路由协议知识；

Module 4简要介绍了组播地址、IGMP、PIM-SM等，帮助读者了解组播基础知识、常用组播协议基本原理以及组播应用。

Module 5通过丰富的实例分析阐述了如何灵活使用各种工具实现路由的控制和选择。帮助读者提高综合规划和灵活使用路由协议的能力。

Module 6详细介绍了VLAN原理及其实现，包括VLAN二层互通和三层路由等，帮助读者全面深入地了解VLAN工作原理及其在VRP上的配置；

Module 7对STP协议进行了详细的描述，包括STP、RSTP、MSTP三部分内容，使读者掌握STP协议工作原理以及在VRP上的实现。

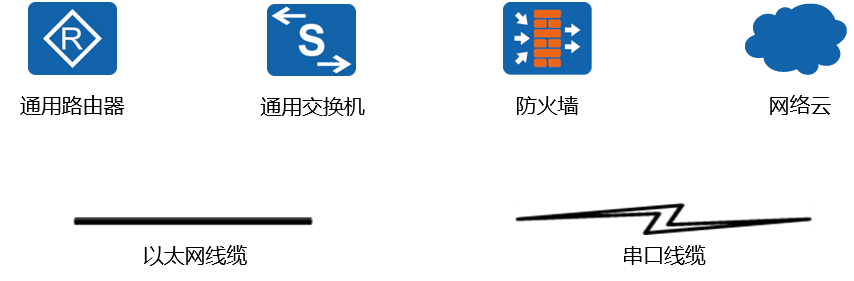
本书引导读者循序渐进地掌握路由技术在华为产品中的实现，读者也可以根据自身情况选择感兴趣的章节阅读。

**读者知识背景**

为了更好地掌握本书内容，阅读本书的读者应首先具备以下基本条件之一：

1. 参加过HCIA培训
2. 通过HCIA考试
3. 熟悉TCP/IP协议栈工作原理，熟悉IP地址
4. 熟悉以太网交换机基本工作原理

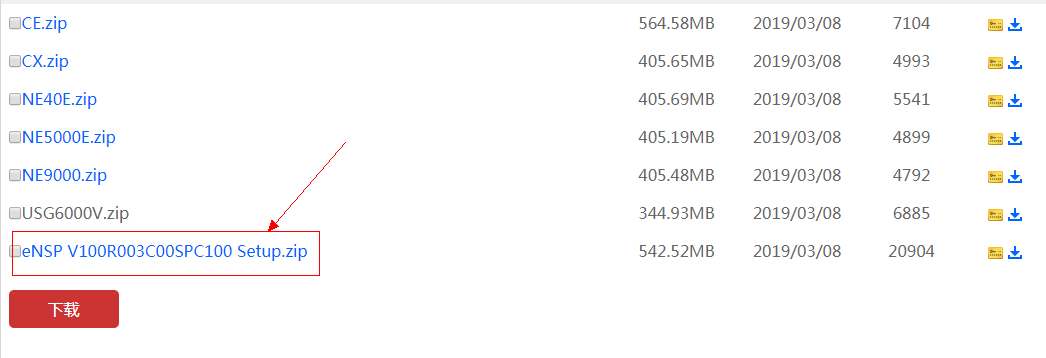
# 本书常用图标



# 实验环境说明

## eNSP安装

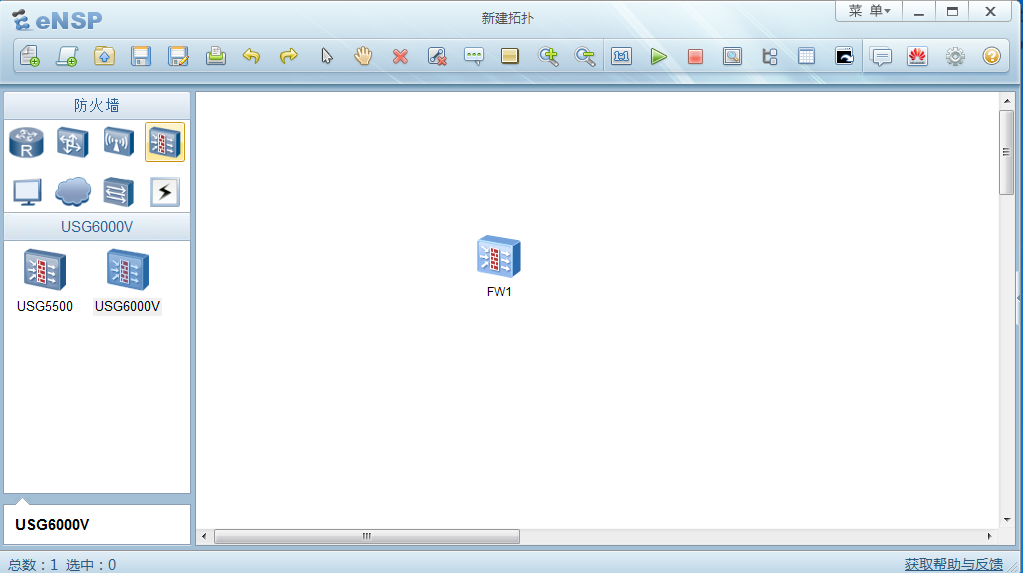
1. 下载eNSP：<https://support.huawei.com/enterprise/zh/tool/ensp-TL1000000015/23917110>
2. 进入链接后点击下载eNSP最新版本



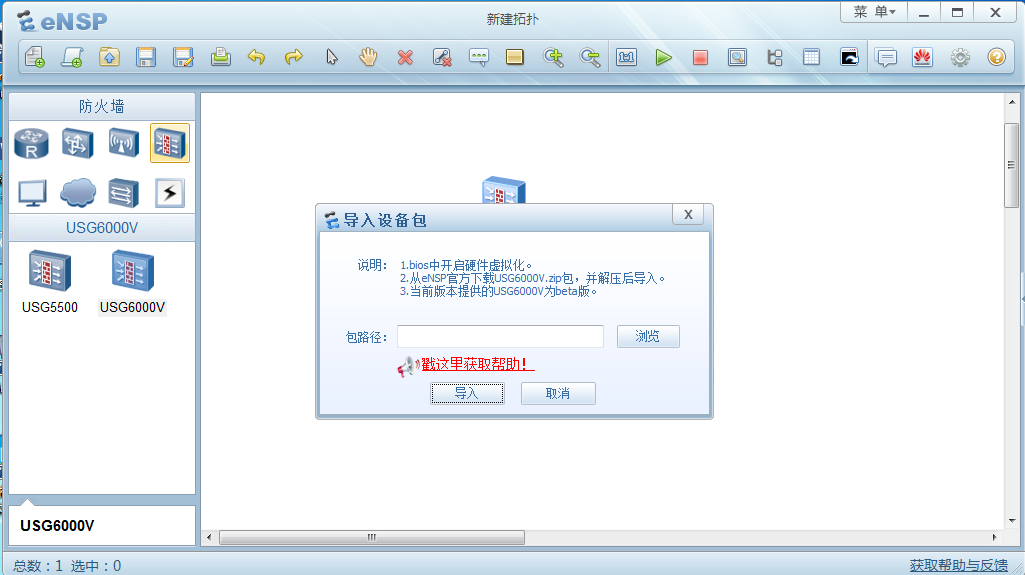
1. 具体软件安装见下方的软件安装指南



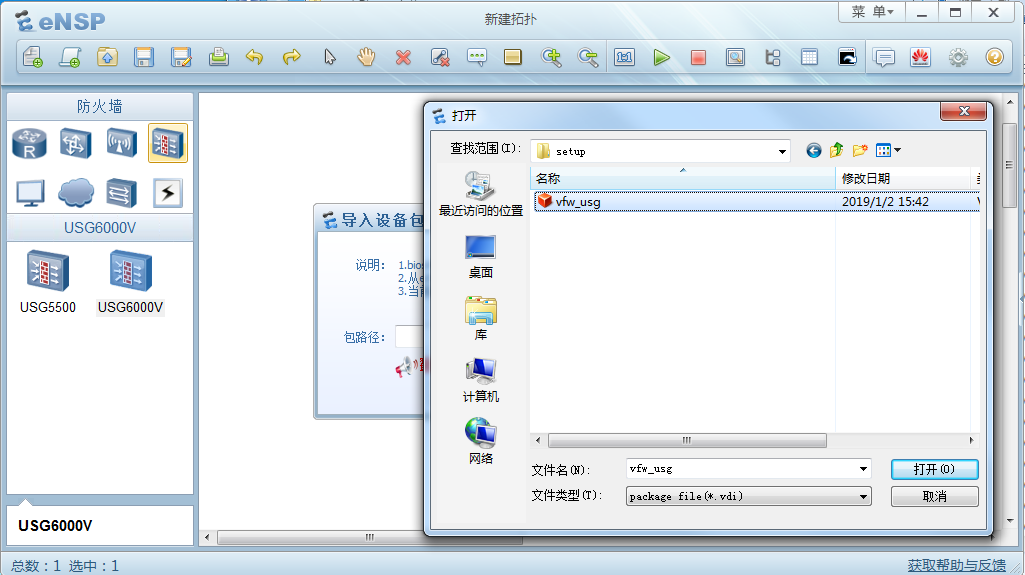
1. 关于在eNSP中使用几个特殊设备时的操作：
2. 只要用到以下设备，都需去官网上下载相应的镜像文件
3. 例如在eNSP中选用USG6000V后，右键点击启动：



1. 启动设备后会弹出导入设备包的对话框：



1. 点击“浏览”——找到从官网上下载的镜像文件导入即可。



## 组网介绍

本实验环境面向准备HCIP-IERS考试的网络工程师，实验设备包括路由器5台，交换机4台，防火墙1台。每套实验环境适用于2名学员同时上机操作。

## 设备介绍

为了满足HCIP-IERS实验需要，建议每套实验环境采用以下配置：

设备名称、型号与版本的对应关系如下：

|  |  |  |
| --- | --- | --- |
| 设备名称 | 设备型号 | 软件版本 |
| R1 | AR 2220E | V2R7 |
| R2 | AR 2220E | V2R7 |
| R3 | AR 2220E | V2R7 |
| R4 | AR 2220E | V2R7 |
| R5 | AR 2220E | V2R7 |
| S1 | S5720-36C-EI-AC | V2R8 |
| S2 | S5720-36C-EI-AC | V2R8 |
| S3 | S5720-36C-EI-AC | V2R8 |
| S4 | S5720-36C-EI-AC | V2R8 |
| FW1 | USG6306E-AC | V100R001C30 |

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第一章 OSPF协议特性与配置

实验 1-1 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

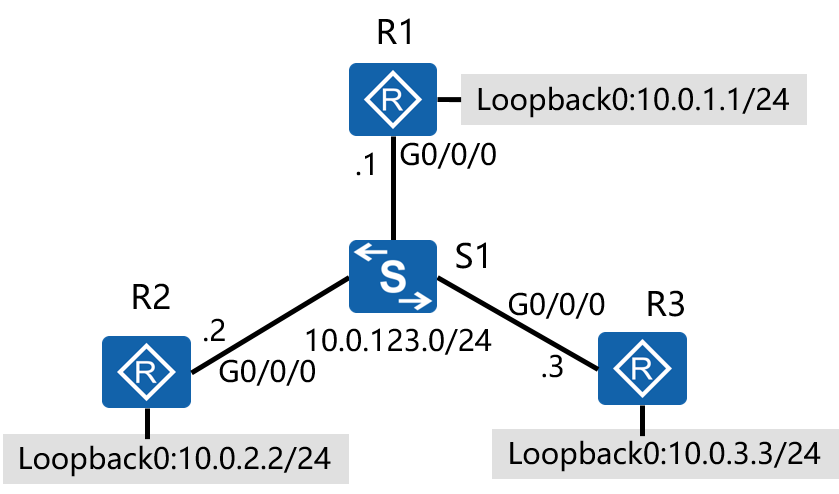


图1-1 OSPF单区域

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

1. 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

1. 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

[R1-ospf-1-area-0.0.0.0]quit

[R1-ospf-1]quit

[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

[R2-ospf-1-area-0.0.0.0]quit

[R2-ospf-1]quit

[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

[R3-ospf-1-area-0.0.0.0]quit

[R3-ospf-1]quit

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 LoopBack0

10.0.1.255/32 Direct 0 0 D 127.0.0.1 LoopBack0

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 GigabitEthernet0/0/0

10.0.123.255/32 Direct 0 0 D 127.0.0.1 GigabitEthernet0/0/0

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

127.255.255.255/32Direct 0 0 D 127.0.0.1 InLoopBack0

255.255.255.255/32Direct 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

Applications Supported: MPLS Traffic-Engineering

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: 9

RFC 1583 Compatible

Retransmission limitation is disabled

Area Count: 1 Nssa Area Count: 0

ExChange/Loading Neighbors: 0

Process total up interface count: 2

Process valid up interface count: 1

Area: 0.0.0.0 (MPLS TE not enabled)

Authtype: Simple Area flag: Normal

SPF scheduled Count: 9

ExChange/Loading Neighbors: 0

Router ID conflict state: Normal

Area interface up count: 2

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

Interface: 10.0.123.1 (GigabitEthernet0/0/0)

Cost: 1 State: DR Type: Broadcast MTU: 1500

Priority: 1

Designated Router: 10.0.123.1

Backup Designated Router: 10.0.123.2

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DR，后面列出了该网络上的BDR（10.0.123.2）。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

----------------------------------------------------------------------------

Total Peer(s): 2

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]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 1569 48 80000005 0

Router 10.0.2.2 10.0.2.2 1568 48 80000006 0

Router 10.0.1.1 10.0.1.1 1567 48 80000008 0

Network 10.0.123.110.0.1.1 1567 36 80000004 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，R1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10.0.1.1。

[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 : 430

Len : 48

Options : E

seq# : 80000009

chksum : 0x8188

Link count: 2

\* Link ID: 10.0.1.1

Data : 255.255.255.255

Link Type: StubNet

Metric : 0

Priority : Medium

\* Link ID : 10.0.123.1

Data : 10.0.123.1

Link Type: TransNet

Metric : 1

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。第二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10.0.123.1，Data为该网段上本地端口的IP地址10.0.123.1；

[R1]display ospf lsdb network self-originate

OSPF Process 1 with Router ID 10.0.1.1

Area: 0.0.0.0

Link State Database

Type : Network

Ls id : 10.0.123.1

Adv rtr : 10.0.1.1

Ls age : 1662

Len : 36

Options : E

seq# : 80000005

chksum : 0x3d58

Net mask : 255.255.255.0

Priority : Low

Attached Router 10.0.1.1

Attached Router 10.0.2.2

Attached Router 10.0.3.3

上面的输出是R1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。

1. 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10.0.123.1，BDR的接口IP为10.0.123.2。

[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: 10.0.123.1 BDR: 10.0.123.2 MTU: 0

Dead timer due in 40 sec

Retrans timer interval: 5

Neighbor is up for 01:03:35

Authentication Sequence: [ 0 ]

Router ID: 10.0.3.3 Address: 10.0.123.3

State: Full Mode:Nbr is Master Priority: 1

DR: 10.0.123.1 BDR: 10.0.123.2 MTU: 0

Dead timer due in 33 sec

Retrans timer interval: 5

Neighbor is up for 01:02:27

Authentication Sequence: [ 0 ]

有可能每个人的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R1的OSPF进程。

<R1>reset ospf process

Warning: The OSPF process will be reset. Continue? [Y/N]:y

[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 34 sec

Retrans timer interval: 0

Neighbor is up for 00:00:19

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 39 sec

Retrans timer interval: 5

Neighbor is up for 00:00:19

Authentication Sequence: [ 0 ]

当重置R1的OSPF进程以后，原来该网络上的BDR 10.0.123.2成为了新的DR，原来的DROther 10.0.123.3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]interface GigabitEthernet 0/0/0

[R1-GigabitEthernet0/0/0]shut

[R1-GigabitEthernet0/0/0]undo shut

<R2>debugging ospf 1 event

<R2>terminal debugging

[R2]interface GigabitEthernet 0/0/0

[R2-GigabitEthernet0/0/0]shut

[R2-GigabitEthernet0/0/0]undo shut

<R3>debugging ospf 1 event

<R3>terminal debugging

[R3]interface GigabitEthernet 0/0/0

[R3-GigabitEthernet0/0/0]shutdown

[R3-GigabitEthernet0/0/0]undo shutdown

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]

Oct 12 2016 11:54:59.220.1+00:00 R3 RM/6/RMDEBUG:

FileID: 0xd017802c Line: 1326 Level: 0x20

OSPF 1: Intf 10.0.123.3 Rcv InterfaceUp State Down -> Waiting.

[R3-GigabitEthernet0/0/0]

Oct 12 2016 11:54:59.230.1+00:00 R3 RM/6/RMDEBUG:

FileID: 0xd017802c Line: 1440 Level: 0x20

OSPF 1 Send Hello Interface Up on 10.0.123.3

[R3-GigabitEthernet0/0/0]

Oct 12 2016 11:55:08.550.2+00:00 R3 RM/6/RMDEBUG:

FileID: 0xd017802d Line: 1200 Level: 0x20

OSPF 1: Nbr 10.0.123.1 Rcv HelloReceived State Down -> Init.

[R3-GigabitEthernet0/0/0]

Oct 12 2016 11:55:09.530.2+00:00 R3 RM/6/RMDEBUG:

FileID: 0xd017802d Line: 1200 Level: 0x20

OSPF 1: Nbr 10.0.123.2 Rcv HelloReceived State Down -> Init.

[R3-GigabitEthernet0/0/0]

Oct 12 2016 11:55:18.540.2+00:00 R3 RM/6/RMDEBUG:

FileID: 0xd017802d Line: 1796 Level: 0x20

OSPF 1: Nbr 10.0.123.1 Rcv 2WayReceived State Init -> 2Way.

[R3-GigabitEthernet0/0/0]

Oct 12 2016 11:55:19.570.2+00:00 R3 RM/6/RMDEBUG:

FileID: 0xd017802d Line: 1796 Level: 0x20

OSPF 1: Nbr 10.0.123.2 Rcv 2WayReceived State Init -> 2Way.

[R3-GigabitEthernet0/0/0]

Oct 12 2016 11:55:39.370.1+00:00 R3 RM/6/RMDEBUG:

FileID: 0xd017802d Line: 1796 Level: 0x20

OSPF 1: Nbr 10.0.123.1 Rcv AdjOk? State 2Way -> ExStart.

[R3-GigabitEthernet0/0/0]

Oct 12 2016 11:55:39.370.2+00:00 R3 RM/6/RMDEBUG:

FileID: 0xd017802d Line: 1796 Level: 0x20

OSPF 1: Nbr 10.0.123.2 Rcv AdjOk? State 2Way -> ExStart.

[R3-GigabitEthernet0/0/0]

Oct 12 2016 11:55:39.370.3+00:00 R3 RM/6/RMDEBUG:

FileID: 0xd017802c Line: 2127 Level: 0x20

OSPF 1 Send Hello Interface State Changed on 10.0.123.3

[R3-GigabitEthernet0/0/0]

Oct 12 2016 11:55:39.370.4+00:00 R3 RM/6/RMDEBUG:

FileID: 0xd017802c Line: 2138 Level: 0x20

OSPF 1: Intf 10.0.123.3 Rcv WaitTimer State Waiting -> DR.

[R3-GigabitEthernet0/0/0]

Oct 12 2016 11:55:39.390.1+00:00 R3 RM/6/RMDEBUG:

FileID: 0xd017802d Line: 1909 Level: 0x20

OSPF 1: Nbr 10.0.123.1 Rcv NegotiationDone State ExStart -> Exchange.

[R3-GigabitEthernet0/0/0]

Oct 12 2016 11:55:39.390.2+00:00 R3 RM/6/RMDEBUG:

FileID: 0xd017802d Line: 1909 Level: 0x20

OSPF 1: Nbr 10.0.123.2 Rcv NegotiationDone State ExStart -> Exchange.

[R3-GigabitEthernet0/0/0]

Oct 12 2016 11:55:39.400.1+00:00 R3 RM/6/RMDEBUG:

FileID: 0xd017802d Line: 2021 Level: 0x20

OSPF 1: Nbr 10.0.123.1 Rcv ExchangeDone State Exchange -> Loading.

[R3-GigabitEthernet0/0/0]

Oct 12 2016 11:55:39.400.2+00:00 R3 RM/6/RMDEBUG:

FileID: 0xd017802d Line: 2423 Level: 0x20

OSPF 1: Nbr 10.0.123.1 Rcv LoadingDone State Loading -> Full.

[R3-GigabitEthernet0/0/0]

Oct 12 2016 11:55:39.400.3+00:00 R3 RM/6/RMDEBUG:

FileID: 0xd017802d Line: 2021 Level: 0x20

OSPF 1: Nbr 10.0.123.2 Rcv ExchangeDone State Exchange -> Loading.

[R3-GigabitEthernet0/0/0]

Oct 12 2016 11:55:39.400.4+00:00 R3 RM/6/RMDEBUG:

FileID: 0xd017802d Line: 2423 Level: 0x20

OSPF 1: Nbr 10.0.123.2 Rcv LoadingDone State Loading -> Full.

<R1>undo debugging all

<R2>undo debugging all

<R3>undo debugging all

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。

1. 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 LoopBack0

10.0.1.255/32 Direct 0 0 D 127.0.0.1 LoopBack0

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 GigabitEthernet0/0/0

10.0.123.255/32 Direct 0 0 D 127.0.0.1 GigabitEthernet0/0/0

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

127.255.255.255/32Direct 0 0 D 127.0.0.1 InLoopBack0

255.255.255.255/32Direct 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 LoopBack0

10.0.1.255/32 Direct 0 0 D 127.0.0.1 LoopBack0

10.0.2.2/24 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 GigabitEthernet0/0/0

10.0.123.255/32 Direct 0 0 D 127.0.0.1 GigabitEthernet0/0/0

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

127.255.255.255/32Direct 0 0 D 127.0.0.1 InLoopBack0

255.255.255.255/32Direct 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

1. 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 LoopBack0

10.0.1.255/32 Direct 0 0 D 127.0.0.1 LoopBack0

10.0.2.2/24 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 GigabitEthernet0/0/0

10.0.123.255/32 Direct 0 0 D 127.0.0.1 GigabitEthernet0/0/0

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

127.255.255.255/32Direct 0 0 D 127.0.0.1 InLoopBack0

255.255.255.255/32Direct 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

[R1-GigabitEthernet0/0/0]quit

[R3]interface GigabitEthernet 0/0/0

[R3-GigabitEthernet0/0/0]ospf cost 10

[R3-GigabitEthernet0/0/0]quit

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 LoopBack0

10.0.1.255/32 Direct 0 0 D 127.0.0.1 LoopBack0

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 GigabitEthernet0/0/0

10.0.123.255/32 Direct 0 0 D 127.0.0.1 GigabitEthernet0/0/0

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

127.255.255.255/32Direct 0 0 D 127.0.0.1 InLoopBack0

255.255.255.255/32Direct 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 LoopBack0

10.0.3.255/32 Direct 0 0 D 127.0.0.1 LoopBack0

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 GigabitEthernet0/0/0

10.0.123.255/32 Direct 0 0 D 127.0.0.1 GigabitEthernet0/0/0

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

127.255.255.255/32Direct 0 0 D 127.0.0.1 InLoopBack0

255.255.255.255/32Direct 0 0 D 127.0.0.1 InLoopBack0

1. 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

[R1-ospf-1]quit

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 LoopBack0

10.0.1.255/32 Direct 0 0 D 127.0.0.1 LoopBack0

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 GigabitEthernet0/0/0

10.0.123.255/32 Direct 0 0 D 127.0.0.1 GigabitEthernet0/0/0

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

127.255.255.255/32Direct 0 0 D 127.0.0.1 InLoopBack0

255.255.255.255/32Direct 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: 1

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

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

[R1-ospf-1]quit

[R2]ospf 1

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

[R1-ospf-1]quit

[R3]ospf 1

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

[R1-ospf-1]quit

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 LoopBack0

10.0.1.255/32 Direct 0 0 D 127.0.0.1 LoopBack0

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 GigabitEthernet0/0/0

10.0.123.255/32 Direct 0 0 D 127.0.0.1 GigabitEthernet0/0/0

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

127.255.255.255/32Direct 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**

[V200R007C00SPC600]

#

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 10.0.1.1 0.0.0.0

network 10.0.123.1 0.0.0.0

#

return

<R2>**display current-configuration**

[V200R007C00SPC600]

#

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 10.0.2.2 0.0.0.0

network 10.0.123.2 0.0.0.0

#

return

<R3>**display current-configuration**

[V200R007C00SPC600]

#

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 10.0.3.3 0.0.0.0

network 10.0.123.3 0.0.0.0

#

return

实验 1-2 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**

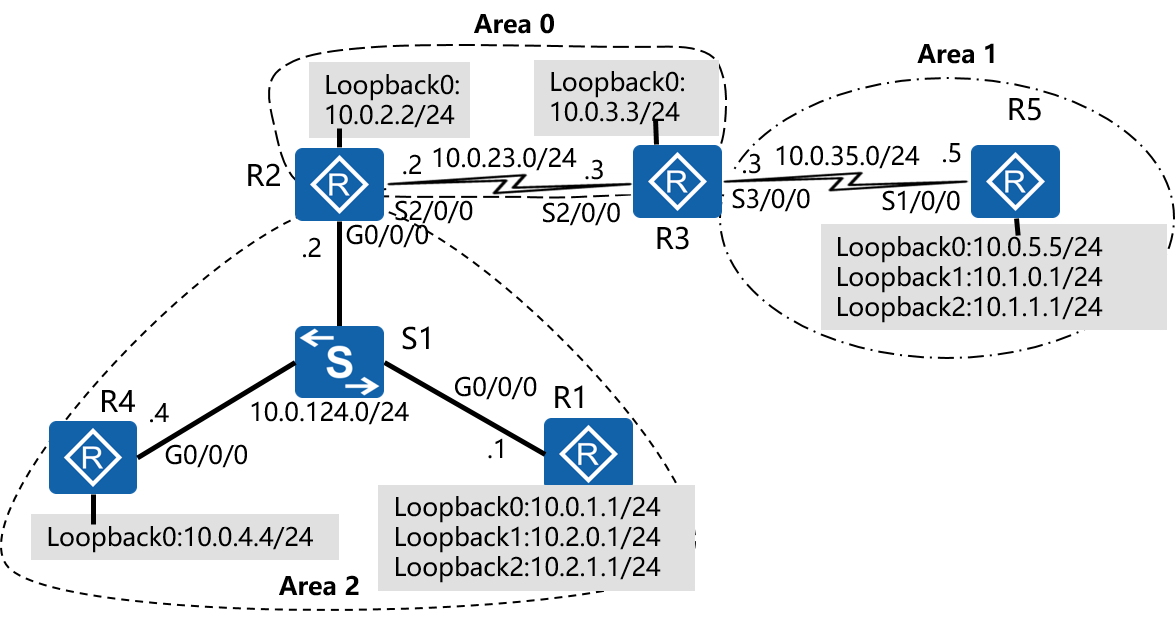


图1-2 OSPF多区域

## **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之间也通过专线相连。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，你在区域的边界配置了自动汇总。

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

1. 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]quit

[R1]interface LoopBack 0

[R1-LoopBack0]ip address 10.0.1.1 24

[R1-LoopBack0]quit

[R1]interface LoopBack 1

[R1-LoopBack1]ip address 10.2.0.1 24

[R1-LoopBack1]quit

[R1]interface LoopBack 2

[R1-LoopBack2]ip address 10.2.1.1 24

[R1-LoopBack2]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 10.0.124.2 24

[R2-GigabitEthernet0/0/0]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 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

<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]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

[R5]interface LoopBack 1

[R5-LoopBack1]ip address 10.1.0.1 24  
[R5-LoopBack1]quit

[R5]interface LoopBack 2

[R5-LoopBack2]ip address 10.1.1.1 24

[R5-LoopBack2]quit

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

1. 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]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 LoopBack0

10.0.1.255/32 Direct 0 0 D 127.0.0.1 LoopBack0

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 GigabitEthernet0/0/0

10.0.124.255/32 Direct 0 0 D 127.0.0.1 GigabitEthernet0/0/0

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

10.2.0.0/24 Direct 0 0 D 10.2.0.1 LoopBack1

10.2.0.1/32 Direct 0 0 D 127.0.0.1 LoopBack1

10.2.0.255/32 Direct 0 0 D 127.0.0.1 LoopBack1

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 LoopBack2

10.2.1.255/32 Direct 0 0 D 127.0.0.1 LoopBack2

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

127.255.255.255/32Direct 0 0 D 127.0.0.1 InLoopBack0

255.255.255.255/32Direct 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 (MPLS TE not enabled)

Authtype: None Area flag: Normal

SPF scheduled Count: 18

ExChange/Loading Neighbors: 0

Router ID conflict state: Normal

Area interface up count: 2

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 (MPLS TE not enabled)

Authtype: None Area flag: Normal

SPF scheduled Count: 16

ExChange/Loading Neighbors: 0

Router ID conflict state: Normal

Area interface up count: 1

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 10.0.1.0 10.0.2.2 143 28 80000001 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

1. 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 : 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 1 D 10.0.124.1 GigabitEthernet0/0/0

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 : 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 1563 D 10.0.23.2 Serial2/0/0

10.0.2.0/24 OSPF 10 1562 D 10.0.23.2 Serial2/0/0

10.0.4.0/24 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

[R3-ospf-1-area-0.0.0.1]quit

[R3-ospf-1]quit

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 : 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 1563 D 10.0.23.2 Serial2/0/0

10.0.2.0/24 OSPF 10 1562 D 10.0.23.2 Serial2/0/0

10.0.4.0/24 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 : 6 Routes : 6

OSPF routing table status : <Active>

Destinations : 6 Routes : 6

Destination/Mask Proto Pre Cost Flags NextHop Interface

10.0.1.0/24 OSPF 10 1 D 10.0.124.1 GigabitEthernet0/0/0

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

1. 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

[R1-ospf-1]bandwidth-reference 10000

[R1-ospf-1]quit

[R2]ospf 1

[R2-ospf-1]bandwidth-reference 10000

[R2-ospf-1]quit

[R3]ospf 1

[R3-ospf-1]bandwidth-reference 10000

[R3-ospf-1]quit

[R4]ospf 1

[R4-ospf-1]bandwidth-reference 10000

[R4-ospf-1]quit

[R5]ospf 1

[R5-ospf-1]bandwidth-reference 10000

[R5-ospf-1]quit

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 : 6 Routes : 6

OSPF routing table status : <Active>

Destinations : 6 Routes : 6

Destination/Mask Proto Pre Cost Flags NextHop Interface

10.0.1.0/24 OSPF 10 100 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 10 100 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。

1. 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 1

[R1-ospf-1]import-route direct

[R1-ospf-1]asbr-summary 10.2.0.0 255.255.254.0

[R1-ospf-1]quit

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 150 100 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 10 100 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 ospf 150 100 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 10 100 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。

1. 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

[R4-ospf-1]quit

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]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

0.0.0.0/0 O\_ASE 150 101 D 10.0.124.4 GigabitEthernet0/0/0

10.0.1.0/24 ospf 10 100 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 10 100 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

1. 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]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

0.0.0.0/0 O\_ASE 150 101 D 10.0.124.4 GigabitEthernet0/0/0

10.0.2.0/24 OSPF 10 100 D 10.0.124.2 GigabitEthernet0/0/0

10.0.3.0/24 OSPF 10 65635 D 10.0.124.2 GigabitEthernet0/0/0

10.0.4.0/24 OSPF 10 100 D 10.0.124.4 GigabitEthernet0/0/0

10.0.5.0/24 OSPF 10 131170 D 10.0.124.2 GigabitEthernet0/0/0

10.0.23.0/24 OSPF 10 65635 D 10.0.124.2 GigabitEthernet0/0/0

10.0.35.0/24 OSPF 10 131170 D 10.0.124.2 GigabitEthernet0/0/0

10.1.0.0/23 OSPF 10 131170 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 1

[R1-ospf-1]preference 20

[R1-ospf-1]preference ase 50

[R1-ospf-1]quit

[R4]ospf 1

[R4-ospf-1]preference 20

[R4-ospf-1]preference ase 50

[R4-ospf-1]quit

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]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

0.0.0.0/0 O\_ASE 50 101 D 10.0.124.4 GigabitEthernet0/0/0

10.0.2.0/24 OSPF 20 100 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 20 100 D 10.0.124.4 GigabitEthernet0/0/0

10.0.5.0/24 OSPF 20 131170 D 10.0.124.2 GigabitEthernet0/0/0

10.0.23.0/24 OSPF 20 65635 D 10.0.124.2 GigabitEthernet0/0/0

10.0.35.0/24 OSPF 20 131170 D 10.0.124.2 GigabitEthernet0/0/0

10.1.0.0/23 OSPF 20 131170 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**

[V200R007C00SPC600]

#

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 10.0.1.1 0.0.0.0

network 10.0.124.1 0.0.0.0

#

return

<R2>**display current-configuration**

[V200R007C00SPC600]

#

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 10.0.2.2 0.0.0.0

network 10.0.23.2 0.0.0.0

area 0.0.0.2

network 10.0.124.2 0.0.0.0

#

return

<R3>**display current-configuration**

[V200R007C00SPC600]

#

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**

[V200R007C00SPC600]

#

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**

[V200R007C00SPC600]

#

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 1-3 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**

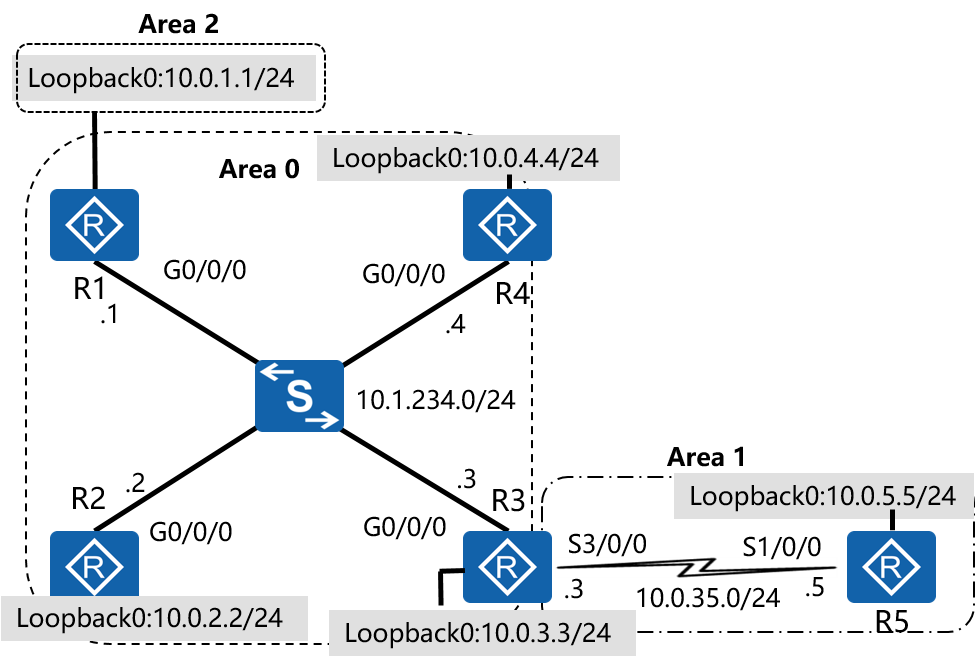


图1-3 OSPF的邻接关系和LSA

## **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

1. 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]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 10.1.234.2 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 10.1.234.3 24

[R3-GigabitEthernet0/0/0]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 10.1.234.4 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

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

1. 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]quit

[R1-ospf-1]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]quit

[R1-ospf-1]quit

[R1]interface LoopBack 0

[R1-LoopBack0]ospf network-type broadcast

[R1-LoopBack0]quit

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]quit

[R2-ospf-1]quit

[R2-]interface LoopBack 0

[R2-LoopBack0]ospf network-type broadcast

[R2-LoopBack0]quit

[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]quit

[R4-ospf-1]quit

[R4-]interface LoopBack 0

[R4-LoopBack0]ospf network-type broadcast

[R4-LoopBack0]quit

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]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

[R5-ospf-1-area-0.0.0.1]quit

[R5-ospf-1]quit

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 LoopBack0

10.0.1.255/32 Direct 0 0 D 127.0.0.1 LoopBack0

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 GigabitEthernet0/0/0

10.1.234.255/32 Direct 0 0 D 127.0.0.1 GigabitEthernet0/0/0

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

127.255.255.255/32Direct 0 0 D 127.0.0.1 InLoopBack0

255.255.255.255/32Direct 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

在R1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

Applications Supported: MPLS Traffic-Engineering

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: 22

RFC 1583 Compatible

Retransmission limitation is disabled

Area Count: 2 Nssa Area Count: 0

ExChange/Loading Neighbors: 0

Process total up interface count: 2

Process valid up interface count: 1

Area: 0.0.0.0 (MPLS TE not enabled)

Authtype: None Area flag: Normal

SPF scheduled Count: 22

ExChange/Loading Neighbors: 0

Router ID conflict state: Normal

Area interface up count: 1

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 (MPLS TE not enabled)

Authtype: None Area flag: Normal

SPF scheduled Count: 20

ExChange/Loading Neighbors: 0

Router ID conflict state: Normal

Area interface up count: 1

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。

1. 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

[R3-GigabitEthernet0/0/0]quit

[R2]interface GigabitEthernet 0/0/0

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

[R2-GigabitEthernet0/0/0]quit

[R4]interface GigabitEthernet 0/0/0

[R4-GigabitEthernet0/0/0]ospf dr-priority 0

[R4-GigabitEthernet0/0/0]quit

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]interface GigabitEthernet 0/0/0

[R1-GigabitEthernet0/0/0]shutdown

[R2]interface GigabitEthernet 0/0/0

[R2-GigabitEthernet0/0/0]shutdown

[R3]interface GigabitEthernet 0/0/0

[R3-GigabitEthernet0/0/0]shutdown

[R4]interface GigabitEthernet 0/0/0

[R4-GigabitEthernet0/0/0]shutdown

[R1-GigabitEthernet0/0/0]undo shutdown

[R1-GigabitEthernet0/0/0]quit

[R2-GigabitEthernet0/0/0]undo shutdown

[R2-GigabitEthernet0/0/0]quit

[R3-GigabitEthernet0/0/0]undo shutdown

[R3-GigabitEthernet0/0/0]quit

[R4-GigabitEthernet0/0/0]undo shutdown

[R4-GigabitEthernet0/0/0]quit

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。

1. 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 1

[R5-ospf-1]import-route direct

[R5-ospf-1]quit

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（下面的输出略去了其他路由条目）。

[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 : 236

Len : 28

Options : E

seq# : 80000007

chksum : 0x14e5

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 : 1637

Len : 28

Options : E

seq# : 80000002

chksum : 0x42bf

Net mask : 255.255.255.0

Tos 0 metric: 1563

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。

1. 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。

1. 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**。

<R1>terminal monitor

Info: Current terminal monitor is on

<R1>terminal debugging

Info: Current terminal debugging is on

<R1>debugging ospf packet update

<R1>debugging ospf packet ack

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

Info: This operation may take a few seconds. Please wait for a moment...succeeded.

[R3]

Oct 25 2016 15:32:27+00:00 R3 %%01IFNET/4/LINK\_STATE(l)[58]:The line protocol IP on the interface LoopBack0 has entered the DOWN state

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。

<R1>

Oct 25 2016 15:24:57.790.1+00:00 R1 RM/6/RMDEBUG:

FileID: 0xd0178024 Line: 2271 Level: 0x20

OSPF 1: RECV Packet. Interface: GigabitEthernet0/0/0

<R1>

Oct 25 2016 15:24:57.790.2+00:00 R1 RM/6/RMDEBUG: Source Address: 10.1.234.3

Oct 25 2016 15:24:57.790.3+00:00 R1 RM/6/RMDEBUG: Destination Address: 224.0.0.5

Oct 25 2016 15:24:57.790.4+00:00 R1 RM/6/RMDEBUG: Ver# 2, Type: 4 (Link-State Update)

Oct 25 2016 15:24:57.790.5+00:00 R1 RM/6/RMDEBUG: Length: 64, Router: 10.0.3.3

Oct 25 2016 15:24:57.790.6+00:00 R1 RM/6/RMDEBUG: Area: 0.0.0.0, Chksum: d8ce

Oct 25 2016 15:24:57.790.7+00:00 R1 RM/6/RMDEBUG: AuType: 00

Oct 25 2016 15:24:57.790.8+00:00 R1 RM/6/RMDEBUG: Key(ascii): \* \* \* \* \* \* \* \*

Oct 25 2016 15:24:57.790.9+00:00 R1 RM/6/RMDEBUG: # LSAS: 1

Oct 25 2016 15:24:57.790.10+00:00 R1 RM/6/RMDEBUG: LSA Type 1

Oct 25 2016 15:24:57.790.11+00:00 R1 RM/6/RMDEBUG: LS ID: 10.0.3.3

Oct 25 2016 15:24:57.790.12+00:00 R1 RM/6/RMDEBUG: Adv Rtr: 10.0.3.3

Oct 25 2016 15:24:57.790.13+00:00 R1 RM/6/RMDEBUG: LSA Age: 1

Oct 25 2016 15:24:57.790.14+00:00 R1 RM/6/RMDEBUG: Options: ExRouting:ON

Oct 25 2016 15:24:57.790.15+00:00 R1 RM/6/RMDEBUG: Length: 36, Seq# 80000020

Oct 25 2016 15:24:57.790.16+00:00 R1 RM/6/RMDEBUG: CheckSum: 9090

Oct 25 2016 15:24:57.790.17+00:00 R1 RM/6/RMDEBUG: NtBit: 0 VBit: 0 EBit: 0 BBit: 1

Oct 25 2016 15:24:57.790.18+00:00 R1 RM/6/RMDEBUG: # Links: 1

Oct 25 2016 15:24:57.790.19+00:00 R1 RM/6/RMDEBUG: LinkID: 10.1.234.3

Oct 25 2016 15:24:57.790.20+00:00 R1 RM/6/RMDEBUG: LinkData: 10.1.234.3

Oct 25 2016 15:24:57.790.21+00:00 R1 RM/6/RMDEBUG: LinkType: 2

Oct 25 2016 15:24:57.790.22+00:00 R1 RM/6/RMDEBUG: TOS# 0 Metric 1

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80000020。

<R1>

Oct 25 2016 15:24:58.200.1+00:00 R1 RM/6/RMDEBUG:

FileID: 0xd0178025 Line: 4708 Level: 0x20

OSPF 1: SEND Packet. Interface: GigabitEthernet0/0/0

<R1>

Oct 25 2016 15:24:58.200.2+00:00 R1 RM/6/RMDEBUG: Source Address: 10.1.234.1

Oct 25 2016 15:24:58.200.3+00:00 R1 RM/6/RMDEBUG: Destination Address: 224.0.0.6

Oct 25 2016 15:24:58.200.4+00:00 R1 RM/6/RMDEBUG: Ver# 2, Type: 5 (Link-State Ack)

Oct 25 2016 15:24:58.200.5+00:00 R1 RM/6/RMDEBUG: Length: 44, Router: 10.0.1.1

Oct 25 2016 15:24:58.200.6+00:00 R1 RM/6/RMDEBUG: Area: 0.0.0.0, Chksum: c5ef

Oct 25 2016 15:24:58.200.7+00:00 R1 RM/6/RMDEBUG: AuType: 00

Oct 25 2016 15:24:58.200.8+00:00 R1 RM/6/RMDEBUG: Key(ascii): \* \* \* \* \* \* \* \*

Oct 25 2016 15:24:58.200.9+00:00 R1 RM/6/RMDEBUG: # LSA Headers: 1

Oct 25 2016 15:24:58.200.10+00:00 R1 RM/6/RMDEBUG: LSA Type 1

Oct 25 2016 15:24:58.200.11+00:00 R1 RM/6/RMDEBUG: LS ID: 10.0.3.3

Oct 25 2016 15:24:58.200.12+00:00 R1 RM/6/RMDEBUG: Adv Rtr: 10.0.3.3

Oct 25 2016 15:24:58.200.13+00:00 R1 RM/6/RMDEBUG: LSA Age: 2

Oct 25 2016 15:24:58.200.14+00:00 R1 RM/6/RMDEBUG: Options: ExRouting:ON

Oct 25 2016 15:24:58.200.15+00:00 R1 RM/6/RMDEBUG: Length: 36, Seq# 80000020

Oct 25 2016 15:24:58.200.16+00:00 R1 RM/6/RMDEBUG: CheckSum: 9090

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

[R3-LoopBack0]quit

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>

Oct 25 2016 15:51:26.250.1+00:00 R1 RM/6/RMDEBUG:

FileID: 0xd0178024 Line: 2271 Level: 0x20

OSPF 1: RECV Packet. Interface: GigabitEthernet0/0/0

<R1>

Oct 25 2016 15:51:26.250.2+00:00 R1 RM/6/RMDEBUG: Source Address: 10.1.234.3

Oct 25 2016 15:51:26.250.3+00:00 R1 RM/6/RMDEBUG: Destination Address: 224.0.0.5

Oct 25 2016 15:51:26.250.4+00:00 R1 RM/6/RMDEBUG: Ver# 2, Type: 4 (Link-State Update)

Oct 25 2016 15:51:26.250.5+00:00 R1 RM/6/RMDEBUG: Length: 76, Router: 10.0.3.3

Oct 25 2016 15:51:26.250.6+00:00 R1 RM/6/RMDEBUG: Area: 0.0.0.0, Chksum: 2c6f

Oct 25 2016 15:51:26.250.7+00:00 R1 RM/6/RMDEBUG: AuType: 00

Oct 25 2016 15:51:26.250.8+00:00 R1 RM/6/RMDEBUG: Key(ascii): \* \* \* \* \* \* \* \*

Oct 25 2016 15:51:26.250.9+00:00 R1 RM/6/RMDEBUG: # LSAS: 1

Oct 25 2016 15:51:26.250.10+00:00 R1 RM/6/RMDEBUG: LSA Type 1

Oct 25 2016 15:51:26.250.11+00:00 R1 RM/6/RMDEBUG: LS ID: 10.0.3.3

Oct 25 2016 15:51:26.250.12+00:00 R1 RM/6/RMDEBUG: Adv Rtr: 10.0.3.3

Oct 25 2016 15:51:26.250.13+00:00 R1 RM/6/RMDEBUG: LSA Age: 1

Oct 25 2016 15:51:26.250.14+00:00 R1 RM/6/RMDEBUG: Options: ExRouting:ON

Oct 25 2016 15:51:26.250.15+00:00 R1 RM/6/RMDEBUG: Length: 48, Seq# 8000002a

Oct 25 2016 15:51:26.250.16+00:00 R1 RM/6/RMDEBUG: CheckSum: 2cca

Oct 25 2016 15:51:26.250.17+00:00 R1 RM/6/RMDEBUG: NtBit: 0 VBit: 0 EBit: 0 BBit: 1

Oct 25 2016 15:51:26.250.18+00:00 R1 RM/6/RMDEBUG: # Links: 2

Oct 25 2016 15:51:26.250.19+00:00 R1 RM/6/RMDEBUG: LinkID: 10.1.234.3

Oct 25 2016 15:51:26.250.20+00:00 R1 RM/6/RMDEBUG: LinkData: 10.1.234.3

Oct 25 2016 15:51:26.250.21+00:00 R1 RM/6/RMDEBUG: LinkType: 2

Oct 25 2016 15:51:26.250.22+00:00 R1 RM/6/RMDEBUG: TOS# 0 Metric 1

Oct 25 2016 15:51:26.250.23+00:00 R1 RM/6/RMDEBUG: LinkID: 10.0.3.3

Oct 25 2016 15:51:26.250.24+00:00 R1 RM/6/RMDEBUG: LinkData: 255.255.255.255

Oct 25 2016 15:51:26.250.25+00:00 R1 RM/6/RMDEBUG: LinkType: 3

Oct 25 2016 15:51:26.250.26+00:00 R1 RM/6/RMDEBUG: TOS# 0 Metric 0

R1首先收到BDR的ACK报文。

<R1>

Oct 25 2016 15:51:27.90.1+00:00 R1 RM/6/RMDEBUG:

FileID: 0xd0178024 Line: 2271 Level: 0x20

OSPF 1: RECV Packet. Interface: GigabitEthernet0/0/0

<R1>

Oct 25 2016 15:51:27.90.2+00:00 R1 RM/6/RMDEBUG: Source Address: 10.1.234.2

Oct 25 2016 15:51:27.90.3+00:00 R1 RM/6/RMDEBUG: Destination Address: 224.0.0.5

Oct 25 2016 15:51:27.90.4+00:00 R1 RM/6/RMDEBUG: Ver# 2, Type: 5 (Link-State Ack)

Oct 25 2016 15:51:27.90.5+00:00 R1 RM/6/RMDEBUG: Length: 44, Router: 10.0.2.2

Oct 25 2016 15:51:27.90.6+00:00 R1 RM/6/RMDEBUG: Area: 0.0.0.0, Chksum: 289f

Oct 25 2016 15:51:27.90.7+00:00 R1 RM/6/RMDEBUG: AuType: 00

Oct 25 2016 15:51:27.90.8+00:00 R1 RM/6/RMDEBUG: Key(ascii): \* \* \* \* \* \* \* \*

Oct 25 2016 15:51:27.90.9+00:00 R1 RM/6/RMDEBUG: # LSA Headers: 1

Oct 25 2016 15:51:27.90.10+00:00 R1 RM/6/RMDEBUG: LSA Type 1

Oct 25 2016 15:51:27.90.11+00:00 R1 RM/6/RMDEBUG: LS ID: 10.0.3.3

Oct 25 2016 15:51:27.90.12+00:00 R1 RM/6/RMDEBUG: Adv Rtr: 10.0.3.3

Oct 25 2016 15:51:27.90.13+00:00 R1 RM/6/RMDEBUG: LSA Age: 2

Oct 25 2016 15:51:27.90.14+00:00 R1 RM/6/RMDEBUG: Options: ExRouting:ON

Oct 25 2016 15:51:27.90.15+00:00 R1 RM/6/RMDEBUG: Length: 48, Seq# 8000002a

Oct 25 2016 15:51:27.90.16+00:00 R1 RM/6/RMDEBUG: CheckSum: 2cca

最后是R1自己发送的ACK报文。

<R1>

Oct 25 2016 15:51:26.430.1+00:00 R1 RM/6/RMDEBUG:

FileID: 0xd0178025 Line: 4708 Level: 0x20

OSPF 1: SEND Packet. Interface: GigabitEthernet0/0/0

<R1>

Oct 25 2016 15:51:26.430.2+00:00 R1 RM/6RMDEBUG: Source Address: 10.1.234.1

Oct 25 2016 15:51:26.430.3+00:00 R1 RM/6/RMDEBUG: Destination Address: 224.0.0.6

Oct 25 2016 15:51:26.430.4+00:00 R1 RM/6/RMDEBUG: Ver# 2, Type: 5 (Link-State Ack)

Oct 25 2016 15:51:26.430.5+00:00 R1 RM/6/RMDEBUG: Length: 44, Router: 10.0.1.1

Oct 25 2016 15:51:26.430.6+00:00 R1 RM/6/RMDEBUG: Area: 0.0.0.0, Chksum: 29a1

Oct 25 2016 15:51:26.430.7+00:00 R1 RM/6/RMDEBUG: AuType: 00

Oct 25 2016 15:51:26.430.8+00:00 R1 RM/6/RMDEBUG: Key(ascii): \* \* \* \* \* \* \* \*

Oct 25 2016 15:51:26.430.9+00:00 R1 RM/6/RMDEBUG: # LSA Headers: 1

Oct 25 2016 15:51:26.430.10+00:00 R1 RM/6/RMDEBUG: LSA Type 1

Oct 25 2016 15:51:26.430.11+00:00 R1 RM/6/RMDEBUG: LS ID: 10.0.3.3

Oct 25 2016 15:51:26.430.12+00:00 R1 RM/6/RMDEBUG: Adv Rtr: 10.0.3.3

Oct 25 2016 15:51:26.430.13+00:00 R1 RM/6/RMDEBUG: LSA Age: 1

Oct 25 2016 15:51:26.430.14+00:00 R1 RM/6/RMDEBUG: Options: ExRouting:ON

Oct 25 2016 15:51:26.430.15+00:00 R1 RM/6/RMDEBUG: Length: 48, Seq# 8000002a

Oct 25 2016 15:51:26.430.16+00:00 R1 RM/6/RMDEBUG: CheckSum: 2cca

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。在路由器上观察到的是R1向R2发起了LS Request。

<R1>terminal monitor

Info: Current terminal monitor is on

<R1>terminal debugging

Info: Current terminal debugging is on

<R1>debugging ospf packet update

<R1>debugging ospf packet ack

<R1>debugging ospf packet request

<R1>reset ospf process

Warning: The OSPF process will be reset. Continue? [Y/N]:y

<R1>

Oct 25 2016 16:17:59.750.1+00:00 R1 RM/6/RMDEBUG:

FileID: 0xd0178025 Line: 2993 Level: 0x20

OSPF 1: SEND Packet. Interface: GigabitEthernet0/0/0

<R1>

Oct 25 2016 16:17:59.750.2+00:00 R1 RM/6/RMDEBUG: Source Address: 10.1.234.1

Oct 25 2016 16:17:59.750.3+00:00 R1 RM/6/RMDEBUG: Destination Address: 10.1.234.2

Oct 25 2016 16:17:59.750.4+00:00 R1 RM/6/RMDEBUG: Ver# 2, Type: 3 (Link-State Req)

Oct 25 2016 16:17:59.750.5+00:00 R1 RM/6/RMDEBUG: Length: 156, Router: 10.0.1.1

Oct 25 2016 16:17:59.750.6+00:00 R1 RM/6/RMDEBUG: Area: 0.0.0.0, Chksum: 8b05

Oct 25 2016 16:17:59.750.7+00:00 R1 RM/6/RMDEBUG: AuType: 00

Oct 25 2016 16:17:59.750.8+00:00 R1 RM/6/RMDEBUG: Key(ascii): \* \* \* \* \* \* \* \*

Oct 25 2016 16:17:59.750.9+00:00 R1 RM/6/RMDEBUG: # Requesting LSAs: 11

Oct 25 2016 16:17:59.750.10+00:00 R1 RM/6/RMDEBUG: LSA Type 1

Oct 25 2016 16:17:59.750.11+00:00 R1 RM/6/RMDEBUG: LS ID: 10.0.2.2

Oct 25 2016 16:17:59.750.12+00:00 R1 RM/6/RMDEBUG: Adv Rtr: 10.0.2.2

Oct 25 2016 16:17:59.750.13+00:00 R1 RM/6/RMDEBUG: LSA Type 1

Oct 25 2016 16:17:59.750.14+00:00 R1 RM/6/RMDEBUG: LS ID: 10.0.1.1

Oct 25 2016 16:17:59.750.15+00:00 R1 RM/6/RMDEBUG: Adv Rtr: 10.0.1.1

Oct 25 2016 16:17:59.750.16+00:00 R1 RM/6/RMDEBUG: LSA Type 1

Oct 25 2016 16:17:59.750.17+00:00 R1 RM/6/RMDEBUG: LS ID: 10.0.4.4

Oct 25 2016 16:17:59.750.18+00:00 R1 RM/6/RMDEBUG: Adv Rtr: 10.0.4.4

Oct 25 2016 16:17:59.750.19+00:00 R1 RM/6/RMDEBUG: LSA Type 1

Oct 25 2016 16:17:59.750.20+00:00 R1 RM/6/RMDEBUG: LS ID: 10.0.3.3

Oct 25 2016 16:17:59.750.21+00:00 R1 RM/6/RMDEBUG: Adv Rtr: 10.0.3.3

Oct 25 2016 16:17:59.750.22+00:00 R1 RM/6/RMDEBUG: LSA Type 2

Oct 25 2016 16:17:59.750.23+00:00 R1 RM/6/RMDEBUG: LS ID: 10.1.234.3

Oct 25 2016 16:17:59.750.24+00:00 R1 RM/6/RMDEBUG: Adv Rtr: 10.0.3.3

Oct 25 2016 16:17:59.750.25+00:00 R1 RM/6/RMDEBUG: LSA Type 3

Oct 25 2016 16:17:59.750.26+00:00 R1 RM/6/RMDEBUG: LS ID: 10.0.1.0

Oct 25 2016 16:17:59.750.27+00:00 R1 RM/6/RMDEBUG: Adv Rtr: 10.0.1.1

Oct 25 2016 16:17:59.750.28+00:00 R1 RM/6/RMDEBUG: LSA Type 3

Oct 25 2016 16:17:59.750.29+00:00 R1 RM/6/RMDEBUG: LS ID: 10.0.35.0

Oct 25 2016 16:17:59.750.30+00:00 R1 RM/6/RMDEBUG: Adv Rtr: 10.0.3.3

Oct 25 2016 16:17:59.750.31+00:00 R1 RM/6/RMDEBUG: LSA Type 4

Oct 25 2016 16:17:59.750.32+00:00 R1 RM/6/RMDEBUG: LS ID: 10.0.5.5

Oct 25 2016 16:17:59.750.33+00:00 R1 RM/6/RMDEBUG: Adv Rtr: 10.0.3.3

Oct 25 2016 16:17:59.750.34+00:00 R1 RM/6/RMDEBUG: LSA Type 5

Oct 25 2016 16:17:59.750.35+00:00 R1 RM/6/RMDEBUG: LS ID: 10.0.5.0

Oct 25 2016 16:17:59.750.36+00:00 R1 RM/6/RMDEBUG: Adv Rtr: 10.0.5.5

Oct 25 2016 16:17:59.750.37+00:00 R1 RM/6/RMDEBUG: LSA Type 5

Oct 25 2016 16:17:59.750.38+00:00 R1 RM/6/RMDEBUG: LS ID: 10.0.35.0

Oct 25 2016 16:17:59.750.39+00:00 R1 RM/6/RMDEBUG: Adv Rtr: 10.0.5.5

Oct 25 2016 16:17:59.750.40+00:00 R1 RM/6/RMDEBUG: LSA Type 5

Oct 25 2016 16:17:59.750.41+00:00 R1 RM/6/RMDEBUG: LS ID: 10.0.35.3

Oct 25 2016 16:17:59.750.42+00:00 R1 RM/6/RMDEBUG: Adv Rtr: 10.0.5.5

随后R1收到了来自R3的LS Request。

<R1>

Oct 25 2016 16:30:10.80.1+00:00 R1 RM/6/RMDEBUG:

FileID: 0xd0178024 Line: 2271 Level: 0x20

OSPF 1: RECV Packet. Interface: GigabitEthernet0/0/0

<R1>

Oct 25 2016 16:30:10.80.2+00:00 R1 RM/6/RMDEBUG: Source Address: 10.1.234.3

Oct 25 2016 16:30:10.80.3+00:00 R1 RM/6/RMDEBUG: Destination Address: 10.1.234.1

Oct 25 2016 16:30:10.80.4+00:00 R1 RM/6/RMDEBUG: Ver# 2, Type: 3 (Link-State Req)

Oct 25 2016 16:30:10.80.5+00:00 R1 RM/6/RMDEBUG: Length: 48, Router: 10.0.3.3

Oct 25 2016 16:30:10.80.6+00:00 R1 RM/6/RMDEBUG: Area: 0.0.0.0, Chksum: c4c2

Oct 25 2016 16:30:10.80.7+00:00 R1 RM/6/RMDEBUG: AuType: 00

Oct 25 2016 16:30:10.80.8+00:00 R1 RM/6/RMDEBUG: Key(ascii): \* \* \* \* \* \* \* \*

Oct 25 2016 16:30:10.80.9+00:00 R1 RM/6/RMDEBUG: # Requesting LSAs: 2

Oct 25 2016 16:30:10.80.10+00:00 R1 RM/6/RMDEBUG: LSA Type 1

Oct 25 2016 16:30:10.80.11+00:00 R1 RM/6/RMDEBUG: LS ID: 10.0.1.1

Oct 25 2016 16:30:10.80.12+00:00 R1 RM/6/RMDEBUG: Adv Rtr: 10.0.1.1

Oct 25 2016 16:30:10.80.13+00:00 R1 RM/6/RMDEBUG: LSA Type 3

Oct 25 2016 16:30:10.80.14+00:00 R1 RM/6/RMDEBUG: LS ID: 10.0.1.0

Oct 25 2016 16:30:10.80.15+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**

[V200R007C00SPC600]

#

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**

[V200R007C00SPC600]

#

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**

[V200R007C00SPC600]

#

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**

[V200R007C00SPC600]

#

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**

[V200R007C00SPC600]

#

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 1-4 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**

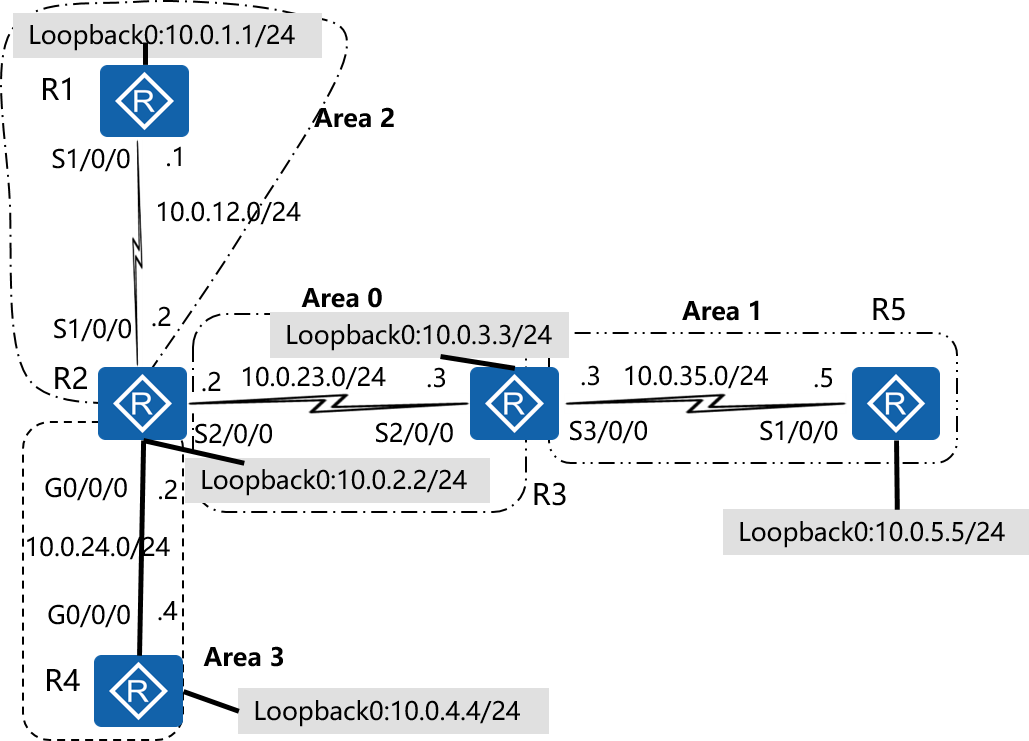


图1-4 OSPF Stub区域与NSSA区域

## **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。R5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

1. 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

1. 配置多区域OSPF

在R1上配置Serial 1/0/0及Loopback 0属于区域2，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]interface 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 LoopBack0

10.0.1.255/32 Direct 0 0 D 127.0.0.1 LoopBack0

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 Serial1/0/0

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 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

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

127.255.255.255/32Direct 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

1. 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 : 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 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

1. 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

1. 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 1

[R3-ospf-1]area 1

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

[R3-ospf-1-area-0.0.0.1]quit

[R3-ospf-1]quit

[R5]ospf 1

[R5-ospf-1]area 1

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

[R5-ospf-1-area-0.0.0.1]quit

[R5-ospf-1]quit

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。

1. 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

Applications Supported: MPLS Traffic-Engineering

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: 14

RFC 1583 Compatible

Retransmission limitation is disabled

Area Count: 2 Nssa Area Count: 1

ExChange/Loading Neighbors: 0

Process total up interface count: 3

Process valid up interface count: 2

Area: 0.0.0.0 (MPLS TE not enabled)

Authtype: None Area flag: Normal

SPF scheduled Count: 14

ExChange/Loading Neighbors: 0

Router ID conflict state: Normal

Area interface up count: 2

Interface: 10.0.3.3 (LoopBack0)

Cost: 0 State: DR Type: Broadcast MTU: 1500

Priority: 1

Designated Router: 10.0.3.3

Backup Designated Router: 0.0.0.0

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 (MPLS TE not enabled)

Authtype: None Area flag: NSSA

SPF scheduled Count: 3

ExChange/Loading Neighbors: 0

NSSA Translator State: Elected

Router ID conflict state: Normal

Area interface up count: 1

NSSA LSA count: 0

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**

[V200R007C00SPC600]

#

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**

[V200R007C00SPC600]

#

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**

[V200R007C00SPC600]

#

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**

[V200R007C00SPC600]

#

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**

[V200R007C00SPC600]

#

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 1-5 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**

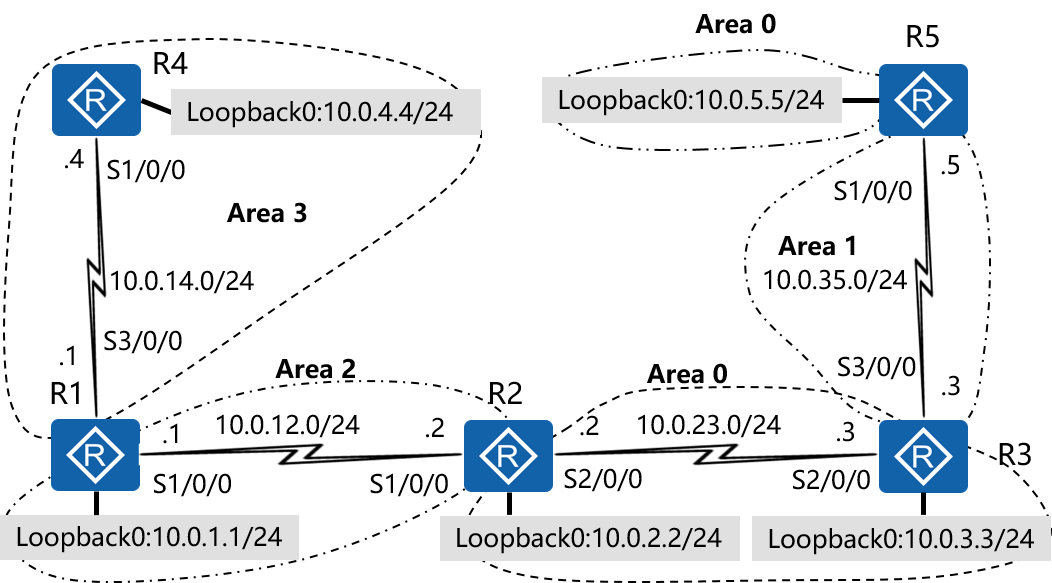


图1-5 OSPF虚电路和区域路由过滤

## **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

1. 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]quit

[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 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 Serial 1/0/0

[R4-Serial1/0/0]ip address 10.0.14.4 24

[R4-Serial1/0/0]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

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

1. 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]quit

[R1-ospf-1]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]quit

[R1-ospf-1]quit

[R1]interface LoopBack 0

[R1-LoopBack0]ospf network-type broadcast

[R1-LoopBack0]quit

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]quit

[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]quit

[R2]interface LoopBack 0

[R2-LoopBack0]ospf network-type broadcast

[R2-LoopBack0]quit

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]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]quit

[R4-ospf-1]quit

[R4]interface LoopBack 0

[R4-LoopBack0]ospf network-type broadcast

[R4-LoopBack0]quit

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]quit

[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-0.0.0.3]quit

[R5-ospf-1]quit

[R5]interface LoopBack 0

[R5-LoopBack0]ospf network-type broadcast

[R5-LoopBack0]quit

1. 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（此处已略去其他输出信息）：

[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。

1. 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

[R3-ospf-1-area-0.0.0.1]quit

[R3-ospf-1]quit

[R5]ospf

[R5-ospf-1]area 1

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

[R5-ospf-1-area-0.0.0.1]quit

[R5-ospf-1]quit

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>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 10.0.5.5 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。

1. 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。

1. 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-acl-basic-2000]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

[R1-ospf-1-area-0.0.0.3]quit

[R1-ospf-1]quit

在R2上查看路由信息过滤的情况。

[R2]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 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**

[V200R007C00SPC600]

#

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**

[V200R007C00SPC600]

#

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**

[V200R007C00SPC600]

#

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**

[V200R007C00SPC600]

#

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**

[V200R007C00SPC600]

#

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 1-6 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**

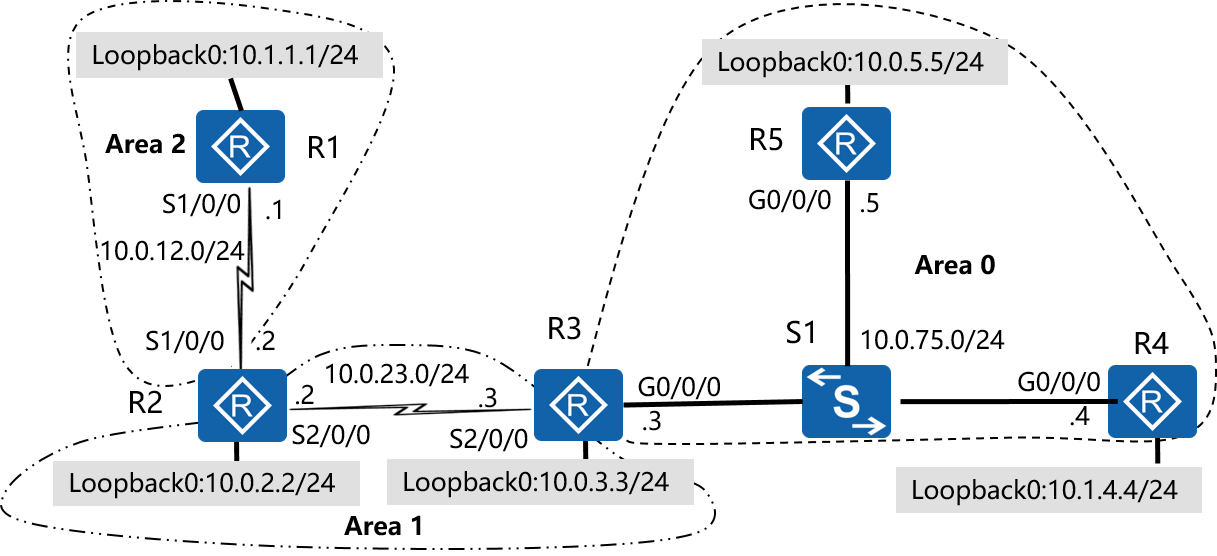


图1-6 OSPF 故障排除

## **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

1. 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 10.1.1.1 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 LoopBack 0

[R2-LoopBack0]ip address 10.0.2.2 24

[R2-LoopBack0]quit

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]quit

[R3]interface GigabitEthernet 0/0/0

[R3-GigabitEthernet0/0/0]ip address 10.0.75.3 25

[R3-GigabitEthernet0/0/0]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 10.0.75.4 24

[R4-GigabitEthernet0/0/0]quit

[R4]interface LoopBack 0

[R4-LoopBack0]ip address 10.1.4.4 24

[R4-LoopBack0]quit

<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]quit

[R5]interface LoopBack 0

[R5-LoopBack0]ip address 10.0.5.5 24

[R5-LoopBack0]quit

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

1. 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]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]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]quit

[R2]interface 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]quit

[R3-ospf-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]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

[R4-ospf-1-area-0.0.0.1]quit

[R4-ospf-1]quit

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]quit

[R5-ospf-1]quit

[R5]interface LoopBack 0

[R5-LoopBack0]ospf network-type broadcast

[R5-LoopBack0]quit

1. 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 11 : Bad packet

0 : Bad version 0 : Bad checksum

41 : 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

0 : Bad net segment 0 : Extern option mismatch

0 : Router id confusion 0 : Bad authentication sequence number

HELLO packet errors:

227 : Netmask mismatch 0 : Hello timer mismatch

0 : Dead timer mismatch 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 0 : Bad packet

0 : Bad version 0 : Bad checksum

245 : 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

0 : Bad net segment 0 : Extern option mismatch

235 : Router id confusion 0 : Bad authentication sequence number

[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 260 : 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

0 : Bad net segment 0 : Extern option mismatch

286 : Router id confusion 0 : Bad authentication sequence number

HELLO packet errors:

260 : Netmask mismatch 0 : Hello timer mismatch

0 : Dead timer mismatch 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

Oct 26 2016 12:34:51+00:00 R5 %%01OSPF/4/CONFLICT\_ROUTERID\_INTF(l)[12]: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

Applications Supported: MPLS Traffic-Engineering

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: 2

RFC 1583 Compatible

Retransmission limitation is disabled

Area Count: 1 Nssa Area Count: 0

ExChange/Loading Neighbors: 0

Process total up interface count: 1

Process valid up interface count: 1

Area: 0.0.0.1 (MPLS TE not enabled)

Authtype: None Area flag: Normal

SPF scheduled Count: 2

ExChange/Loading Neighbors: 0

Router ID conflict state: Normal

Area interface up count: 1

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 1

[R4-ospf-1-area-0.0.0.1]undo network 10.0.75.4 0.0.0.0

[R4-ospf-1-area-0.0.0.1]quit

[R4-ospf-1]undo area 1

[R4-ospf-1]area 0

[R4-ospf-1-area-0.0.0.0]network 10.0.75.4 0.0.0.0

[R4-ospf-1-area-0.0.0.0]quit

[R4-ospf-1]quit

<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 13 : 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

0 : Bad net segment 0 : Extern option mismatch

0 : Router id confusion 0 : Bad authentication sequence number

HELLO packet errors:

13 : Netmask mismatch 0 : Hello timer mismatch

0 : Dead timer mismatch 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

Oct 26 2016 14:30:08.350.1+00:00 R4 RM/6/RMDEBUG:

FileID: 0xd0178024 Line: 2271 Level: 0x20

OSPF 1: RECV Packet. Interface: GigabitEthernet0/0/0

<R4>

Oct 26 2016 14:30:08.360.1+00:00 R4 RM/6/RMDEBUG: Source Address: 10.0.75.3

Oct 26 2016 14:30:08.360.2+00:00 R4 RM/6/RMDEBUG: Destination Address: 224.0.0.5

Oct 26 2016 14:30:08.360.3+00:00 R4 RM/6/RMDEBUG: Ver# 2, Type: 1 (Hello)

Oct 26 2016 14:30:08.360.4+00:00 R4 RM/6/RMDEBUG: Length: 44, Router: 10.0.3.3

Oct 26 2016 14:30:08.360.5+00:00 R4 RM/6/RMDEBUG: Area: 0.0.0.0, Chksum: 9a18

Oct 26 2016 14:30:08.360.6+00:00 R4 RM/6/RMDEBUG: AuType: 00

Oct 26 2016 14:30:08.360.7+00:00 R4 RM/6/RMDEBUG: Key(ascii): \* \* \* \* \* \* \* \*

Oct 26 2016 14:30:08.360.8+00:00 R4 RM/6/RMDEBUG: Net Mask: 255.255.255.128

Oct 26 2016 14:30:08.360.9+00:00 R4 RM/6/RMDEBUG: Hello Int: 10, Option: \_E\_

Oct 26 2016 14:30:08.360.10+00:00 R4 RM/6/RMDEBUG: Rtr Priority: 1, Dead Int: 40

Oct 26 2016 14:30:08.360.11+00:00 R4 RM/6/RMDEBUG: DR: 10.0.75.3

Oct 26 2016 14:30:08.360.12+00:00 R4 RM/6/RMDEBUG: BDR: 0.0.0.0

Oct 26 2016 14:30:08.360.13+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]interface GigabitEthernet 0/0/0

[R3-GigabitEthernet0/0/0]display this

[V200R007C00SPC600]

#

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

[R3-GigabitEthernet0/0/0]quit

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

0 : Bad net segment 0 : Extern option mismatch

0 : Router id confusion 0 : Bad authentication sequence number

HELLO packet errors:

0 : Netmask mismatch 0 : Hello timer mismatch

0 : Dead timer mismatch 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

[R4-GigabitEthernet0/0/0]quit

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

----------------------------------------------------------------------------

清空R4 OSPF计数器，查看OSPF的错误。

<R4>reset ospf counters

<R4>system-view

Enter system view, return user view with Ctrl+Z.

[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 4 : 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

0 : Bad net segment 0 : Extern option mismatch

0 : Router id confusion 0 : Bad authentication sequence number

HELLO packet errors:

0 : Netmask mismatch 4 : Hello timer mismatch

0 : Dead timer mismatch 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]interface GigabitEthernet 0/0/0

[R4-GigabitEthernet0/0/0]undo ospf timer hello

[R4-GigabitEthernet0/0/0]quit

[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。

1. 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

[R1-Serial1/0/0]quit

[R2]interface Serial 1/0/0

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

[R2-Serial1/0/0]quit

配置完成以后在R1上清空OSPF计数器，可以查看到OSPF的错误。

<R1>reset ospf counters

<R1>system-view

Enter system view, return user view with Ctrl+Z.

[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 3 : Bad packet

0 : Bad version 0 : Bad checksum

0 : Bad area id 0 : Drop on unnumbered interface

0 : Bad virtual link 3 : 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

0 : Bad net segment 0 : Extern option mismatch

0 : Router id confusion 0 : Bad authentication sequence number

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 9 : 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

9 : Bad authentication key 0 : Packet too small

0 : Packet size > ip length 0 : Transmit error

0 : Interface down 0 : Unknown neighbor

0 : Bad net segment 0 : Extern option mismatch

0 : Router id confusion 0 : Bad authentication sequence number

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。

1. 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

[R2-ospf-1-area-0.0.0.1]quit

[R2-ospf-1]quit

[R3]ospf 1

[R3-ospf-1]area 1

[R3-ospf-1-area-0.0.0.1]vlink-peer 10.0.2.2

[R3-ospf-1-area-0.0.0.1]quit

[R3-ospf-1]quit

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

[R3-ospf-1-area-0.0.0.0]quit

[R3-ospf-1]quit

[R4]ospf 1

[R4-ospf-1]area 0

[R4-ospf-1-area-0.0.0.0]authentication-mode md5 1 plain huawei

[R4-ospf-1-area-0.0.0.0]quit

[R4-ospf-1]quit

[R5]ospf 1

[R5-ospf-1]area 0

[R5-ospf-1-area-0.0.0.0]authentication-mode md5 1 plain huawei

[R5-ospf-1-area-0.0.0.0]quit

[R5-ospf-1]quit

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]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: 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>reset ospf counters

<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 7 : Bad packet

0 : Bad version 0 : Bad checksum

0 : Bad area id 0 : Drop on unnumbered interface

0 : Bad virtual link 7 : Bad authentication type

9 : Bad authentication key 0 : Packet too small

0 : Packet size > ip length 0 : Transmit error

0 : Interface down 0 : Unknown neighbor

0 : Bad net segment 0 : Extern option mismatch

0 : Router id confusion 0 : Bad authentication sequence number

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 1

[R2-ospf-1]area 0

[R2-ospf-1-area-0.0.0.0]authentication-mode md5 1 plain huawei

[R2-ospf-1-area-0.0.0.0]quit

[R2-ospf-1]quit

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

1. 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 1

[R4-ospf-1]import-route direct

[R4-ospf-1]asbr-summary 10.1.0.0 255.255.0.0

[R4-ospf-1]quit

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 1

[R2-ospf-1]area 2

[R2-ospf-1-area-0.0.0.2]abr-summary 10.1.0.0 255.255.0.0

[R2-ospf-1-area-0.0.0.2]quit

[R2-ospf-1]quit

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

[R4-ospf-1]undo asbr-summary 10.1.0.0 255.255.0.0

[R4-ospf-1]quit

[R5]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 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**

[V200R007C00SPC600]

#

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**

[V200R007C00SPC600]

#

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**

[V200R007C00SPC600]

#

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**

[V200R007C00SPC600]

#

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**

[V200R007C00SPC600]

#

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

第二章 IS-IS协议特性与配置

实验 2-1 IS-IS 配置实验

实验目标

* 掌握IS-IS协议基本配置
* 掌握IS-IS协议DIS优先级修改方式
* 掌握IS-IS协议网络类型修改方式
* 掌握IS-IS协议外部路由引入
* 掌握IS-IS接口cost修改方式
* 掌握IS-IS路由渗透配置方式

拓扑图

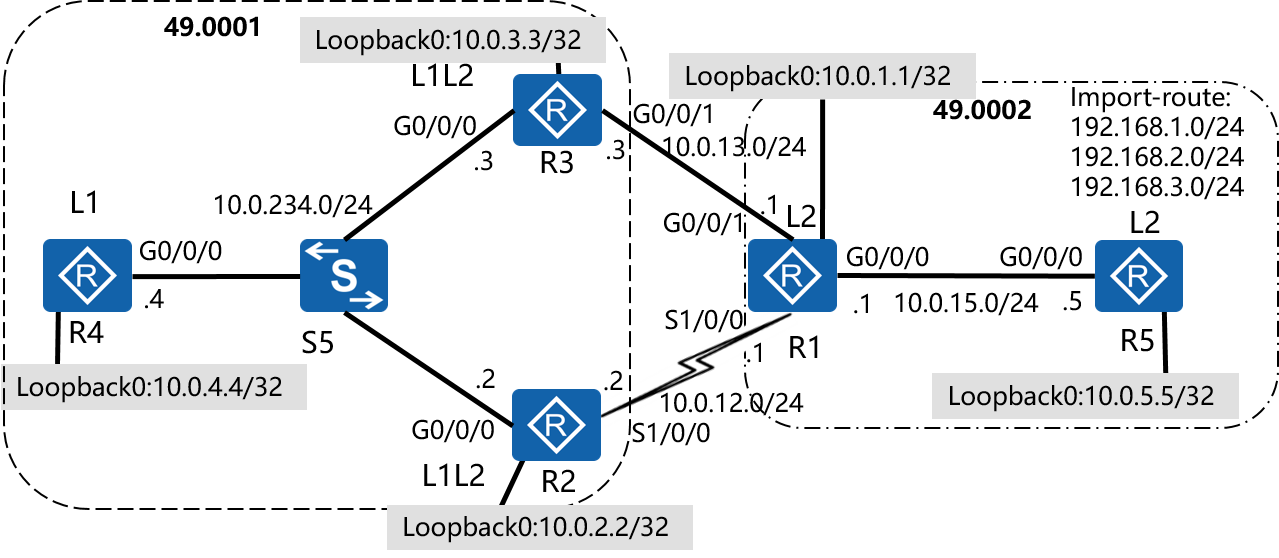


图2-1 IS-IS实验拓扑

场景

使用IS-IS协议作为某网络的IGP，R1和R5运行在49.0002区域Level-2，R2、R3和R4运行在49.0001区域，R4是Level-1路由器，R2和R3作为Level-1-2路由器。要求：R4可以访问R5引入的外部路由；R4连接S5的接口作为DIS；R1和R5之间使用点到点链路；从R4访问R5的上下行流量应该从以太网接口进行转发，可以通过cost和路由渗透进行选路控制；交换机不做额外的配置，仅透明转发。

学习任务

1. IP编址与基本配置

给所有路由器配置IP地址信息。

[R1]interface loopback 0

[R1-LoopBack0]ip address 10.0.1.1 32

[R1-LoopBack0]quit

[R1]interface GigabitEthernet 0/0/0

[R1-GigabitEthernet0/0/0]ip address 10.0.15.1 24

[R1-GigabitEthernet0/0/0]quit

[R1]interface GigabitEthernet 0/0/1

[R1-GigabitEthernet0/0/1]ip address 10.0.13.1 24

[R1-GigabitEthernet0/0/1]quit

[R1]interface interface Serial1/0/0

[R1-Serial1/0/0]ip address 10.0.12.1 24

[R1-Serial1/0/0]quit

[R2]interface LoopBack 0

[R2-LoopBack0]ip address 10.0.2.2 32

[R2-LoopBack0]quit

[R2]interface GigabitEthernet 0/0/0

[R2-GigabitEthernet0/0/0]ip address 10.0.234.2 24

[R2-GigabitEthernet0/0/0]quit

[R2]interface Serial1/0/0

[R2-Serial1/0/0]ip address 10.0.12.2 24

[R2-Serial1/0/0]quit

[R3]interface LoopBack 0

[R3-LoopBack0]ip address 10.0.3.3 32

[R3-LoopBack0]quit

[R3]interface GigabitEthernet 0/0/0

[R3-GigabitEthernet0/0/0]ip address 10.0.234.3 24

[R3-GigabitEthernet0/0/0]quit

[R3]interface GigabitEthernet 0/0/1

[R3-GigabitEthernet0/0/1]ip address 10.0.13.3 24

[R3-GigabitEthernet0/0/1]quit

[R4]interface LoopBack 0

[R4-LoopBack0]ip address 10.0.4.4 32

[R4-LoopBack0]quit

[R4]interface GigabitEthernet 0/0/0

[R4-GigabitEthernet0/0/0]ip address 10.0.234.4 24

[R4-GigabitEthernet0/0/0]quit

[R5]interface LoopBack 0

[R5-LoopBack0]ip address 10.0.5.5 32

[R5-LoopBack0]quit

[R5]interface GigabitEthernet 0/0/0

[R5-GigabitEthernet0/0/0]ip address 10.0.15.5 24

[R5-GigabitEthernet0/0/0]quit

配置完成后，在R1上测试到R2、R3和R5直连接口的连通性。

[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=1 ms

--- 10.0.13.3 ping statistics ---

1 packet(s) transmitted

1 packet(s) received

0.00% packet loss

round-trip min/avg/max = 1/1/1 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=26 ms

--- 10.0.12.2 ping statistics ---

1 packet(s) transmitted

1 packet(s) received

0.00% packet loss

round-trip min/avg/max = 26/26/26 ms

[R1]ping -c 1 10.0.15.5

PING 10.0.15.5: 56 data bytes, press CTRL\_C to break

Reply from 10.0.15.5: bytes=56 Sequence=1 ttl=255 time=1 ms

--- 10.0.15.5 ping statistics ---

1 packet(s) transmitted

1 packet(s) received

0.00% packet loss

round-trip min/avg/max = 1/1/1 ms

测试R4到R2和R3之间直连接口的连通性。

[R4]ping -c 1 10.0.234.2

PING 10.0.234.2: 56 data bytes, press CTRL\_C to break

Reply from 10.0.234.2: bytes=56 Sequence=1 ttl=255 time=1 ms

--- 10.0.234.2 ping statistics ---

1 packet(s) transmitted

1 packet(s) received

0.00% packet loss

round-trip min/avg/max = 1/1/1 ms

[R4]ping -c 1 10.0.234.3

PING 10.0.234.3: 56 data bytes, press CTRL\_C to break

Reply from 10.0.234.3: bytes=56 Sequence=1 ttl=255 time=1 ms

--- 10.0.234.3 ping statistics ---

1 packet(s) transmitted

1 packet(s) received

0.00% packet loss

round-trip min/avg/max = 1/1/1 ms

1. IS-IS协议基本配置

按照拓扑设计逐台配置路由器的isis进程，进程号使用1，以R1为例：

由于R1在区域49.0002，使用network-entity 49.0002.0000.0000.0001。

[R1]isis

[R1-isis-1]network-entity 49.0002.0000.0000.0001.00

默认情况下启用IS-IS进程后，路由器工作在Level-1-2模式，按照规划R1应该是L2模式，因此进行修改：

[R1-isis-1]is-level level-2

[R1-isis-1]quit

将相应的接口启用IS-IS，包括LoopBack接口，不指定IS-IS进程号的情况下默认在进程1下启用：

[R1]interface LoopBack 0

[R1-LoopBack0]isis enable

[R1-LoopBack0]quit

[R1]interface GigabitEthernet 0/0/0

[R1-GigabitEthernet0/0/0]isis enable

[R1-GigabitEthernet0/0/0]quit

[R1]interface GigabitEthernet 0/0/1

[R1-GigabitEthernet0/0/1]isis enable

[R1-GigabitEthernet0/0/1]quit

[R1]interface Serial 1/0/0

[R1-Serial1/0/0]isis enable

[R1-Serial1/0/0]quit

检查IS-IS在接口的启用状况：

[R1]display isis interface

Interface information for ISIS(1)

---------------------------------

Interface Id IPV4.State IPV6.State MTU Type DIS

Loop0 001 Up Down 1500 L1/L2 --

GE0/0/0 001 Up Down 1497 L1/L2 No/No

GE0/0/1 002 Up Down 1497 L1/L2 No/No

S1/0/0 002 Up Down 1500 L1/L2 --

可以看到**ISIS(1)**共启用了4个接口，在IPV4地址下状态为Up。

用相同的方式配置其他路由器，R2和R3工作在Level-1-2模式，因此不需要修改is-level：

[R2]isis 1

[R2-isis-1]network-entity 49.0001.0000.0000.0002.00

[R2-isis-1]quit

[R2]interface LoopBack 0

[R2-LoopBack0]isis enable

[R2-LoopBack0]quit

[R2]interface GigabitEthernet 0/0/0

[R2-GigabitEthernet0/0/0]isis enable

[R2-GigabitEthernet0/0/0]quit

[R2]interface Serial 1/0/0

[R2-Serial1/0/0]isis enable

[R2-Serial1/0/0]quit

在R2上检查IS-IS在接口的启用状况：

[R2]display isis interface

Interface information for ISIS(1)

---------------------------------

Interface Id IPV4.State IPV6.State MTU Type DIS

Loop0 002 Up Down 1500 L1/L2 --

GE0/0/0 001 Up Down 1497 L1/L2 No/No

S1/0/0 001 Up Down 1500 L1/L2 --

在R3上配置IS-IS：

[R3]isis 1

[R3-isis-1]network-entity 49.0001.0000.0000.0003.00

[R3-isis-1]quit

[R3]interface LoopBack 0

[R3-LoopBack0]isis enable

[R3-LoopBack0]quit

[R3]interface GigabitEthernet 0/0/0

[R3-GigabitEthernet0/0/0]isis enable

[R3-GigabitEthernet0/0/0]quit

[R3]interface GigabitEthernet 0/0/1

[R3-GigabitEthernet0/0/1]isis enable

[R3-GigabitEthernet0/0/1]quit

在R3上检查IS-IS在接口的启用状况：

[R3]display isis interface

Interface information for ISIS(1)

---------------------------------

Interface Id IPV4.State IPV6.State MTU Type DIS

Loop0 001 Up Down 1500 L1/L2 --

GE0/0/0 002 Up Down 1497 L1/L2 No/No

GE0/0/1 001 Up Down 1497 L1/L2 No/No

在R4上配置IS-IS：

[R4]isis 1

[R4-isis-1]network-entity 49.0001.0000.0000.0004.00

[R4-isis-1]is-level level-1

[R4-isis-1]quit

[R4]interface LoopBack 0

[R4-LoopBack0]isis enable

[R4-LoopBack0]quit

[R4]interface GigabitEthernet 0/0/0

[R4-GigabitEthernet0/0/0]isis enable

[R4-GigabitEthernet0/0/0]quit

在R4上检查IS-IS在接口的启用状况：

[R4]display isis interface

Interface information for ISIS(1)

---------------------------------

Interface Id IPV4.State IPV6.State MTU Type DIS

Loop0 001 Up Down 1500 L1/L2 --

GE0/0/0 001 Up Down 1497 L1/L2 No/No

在R5上配置IS-IS：

[R5]isis 1

[R5-isis-1]network-entity 49.0002.0000.0000.0005.00

[R5-isis-1]is-level level-2

[R5-isis-1]quit

[R5]interface LoopBack 0

[R5-LoopBack0]isis enable

[R5-LoopBack0]quit

[R5]interface GigabitEthernet 0/0/0

[R5-GigabitEthernet0/0/0]isis enable

[R5-GigabitEthernet0/0/0]quit

在R5上检查IS-IS在接口的启用状况：

[R5]display isis interface

Interface information for ISIS(1)

---------------------------------

Interface Id IPV4.State IPV6.State MTU Type DIS

Loop0 001 Up Down 1500 L1/L2 --

GE0/0/0 001 Up Down 1497 L1/L2 No/No

配置完成后，观察各设备的邻居状态，以R1为例，应该有3个邻居，分别是R2、R3和R5：

[R1]display isis peer

Peer information for ISIS(1)

System Id Interface Circuit Id State HoldTime Type PRI

----------------------------------------------------------------------------

0000.0000.0005 GE0/0/0 0000.0000.0005.01 Up 7s L2 64

0000.0000.0003 GE0/0/1 0000.0000.0001.02 Up 21s L2 64

0000.0000.0002 S1/0/0 0000000001 Up 28s L2 --

Total Peer(s): 3

这里的System Id，类似于其他协议的Router Id，可以看到R2、R3和R5的状态都是Up，邻居状态正常。

继续检查其他设备的邻居状态：

[R2]display isis peer

Peer information for ISIS(1)

System Id Interface Circuit Id State HoldTime Type PRI

----------------------------------------------------------------------------

0000.0000.0001 S1/0/0 0000000001 Up 22s L2 --

0000.0000.0003 GE0/0/0 0000.0000.0004.01 Up 24s L1(L1L2) 64

0000.0000.0004 GE0/0/0 0000.0000.0004.01 Up 7s L1 64

0000.0000.0003 GE0/0/0 0000.0000.0002.01 Up 26s L2(L1L2) 64

Total Peer(s): 4

[R3]display isis peer

Peer information for ISIS(1)

System Id Interface Circuit Id State HoldTime Type PRI

----------------------------------------------------------------------------

0000.0000.0001 GE0/0/1 0000.0000.0001.02 Up 8s L2 64

0000.0000.0002 GE0/0/0 0000.0000.0004.01 Up 30s L1(L1L2) 64

0000.0000.0004 GE0/0/0 0000.0000.0004.01 Up 7s L1 64

0000.0000.0002 GE0/0/0 0000.0000.0002.01 Up 9s L2(L1L2) 64

Total Peer(s): 4

[R4]display isis peer

Peer information for ISIS(1)

System Id Interface Circuit Id State HoldTime Type PRI

----------------------------------------------------------------------------

0000.0000.0003 GE0/0/0 0000.0000.0004.01 Up 29s L1 64

0000.0000.0002 GE0/0/0 0000.0000.0004.01 Up 23s L1 64

Total Peer(s): 2

[R5]display isis peer

Peer information for ISIS(1)

System Id Interface Circuit Id State HoldTime Type PRI

----------------------------------------------------------------------------

0000.0000.0001 GE0/0/0 0000.0000.0005.01 Up 29s L2 64

Total Peer(s): 1

1. 修改DIS优先级

R2、R3和R4在一个广播网络下建立邻居，因此需要选举DIS，默认情况下，DIS优先级都为64，如果优先级相同MAC地址大的接口将成为DIS，我们希望选举更为清晰，因此通过修改R4的DIS优先级来保证其成为DIS。

[R4]interface GigabitEthernet 0/0/0

[R4-GigabitEthernet0/0/0]isis dis-priority 120

[R4-GigabitEthernet0/0/0]quit

[R4]display isis interface

Interface information for ISIS(1)

---------------------------------

Interface Id IPV4.State IPV6.State MTU Type DIS

GE0/0/0 001 Up Down 1497 L1/L2 Yes/No

Loop0 001 Up Down 1500 L1/L2 –

在R2和R3上查看邻居的DIS优先级：

[R2]display isis peer

Peer information for ISIS(1)

System Id Interface Circuit Id State HoldTime Type PRI

----------------------------------------------------------------------------

0000.0000.0001 S1/0/0 0000000001 Up 29s L2 --

0000.0000.0003 GE0/0/0 0000.0000.0004.01 Up 25s L1(L1L2) 64

0000.0000.0004 GE0/0/0 0000.0000.0004.01 Up 8s L1 120

0000.0000.0003 GE0/0/0 0000.0000.0002.01 Up 20s L2(L1L2) 64

Total Peer(s): 4

[R3]display isis peer

Peer information for ISIS(1)

System Id Interface Circuit Id State HoldTime Type PRI

----------------------------------------------------------------------------

0000.0000.0001 GE0/0/1 0000.0000.0001.02 Up 8s L2 64

0000.0000.0002 GE0/0/0 0000.0000.0004.01 Up 22s L1(L1L2) 64

0000.0000.0004 GE0/0/0 0000.0000.0004.01 Up 7s L1 120

0000.0000.0002 GE0/0/0 0000.0000.0002.01 Up 8s L2(L1L2) 64

Total Peer(s): 4

1. 配置IS-IS网络类型

在广播网络中，IS-IS默认会将接口的circuit-type设置为广播模式，并参与DIS的选举。但在拓扑中R1和R5之间的以太网只有两台路由器，我们可以将这两台路由器之间的互联接口设置为点到点模式，进行优化。

[R1]interface GigabitEthernet 0/0/0

[R1-GigabitEthernet0/0/0]isis circuit-type p2p

[R1-GigabitEthernet0/0/0]quit

[R5]interface GigabitEthernet 0/0/0

[R5-GigabitEthernet0/0/0]isis circuit-type p2p

[R5-GigabitEthernet0/0/0]quit

修改circuit-type过程中，邻居会重新建立，检查配置效果，Circuit Id会改变格式，接口的详细信息也会显示p2p，以R1为例：

[R1]display isis peer

Peer information for ISIS(1)

System Id Interface Circuit Id State HoldTime Type PRI

----------------------------------------------------------------------------

0000.0000.0005 GE0/0/0 0000000002 Up 22s L2 --

0000.0000.0003 GE0/0/1 0000.0000.0001.02 Up 27s L2 64

0000.0000.0002 S1/0/0 0000000001 Up 22s L2 --

[R1]display isis interface GigabitEthernet 0/0/0 verbose

Interface information for ISIS(1)

---------------------------------

Interface Id IPV4.State IPV6.State MTU Type DIS

GE0/0/0 003 Up Down 1497 L1/L2 --

Circuit MT State : Standard

Circuit Parameters : p2p

Description : HUAWEI, AR Series, GigabitEthernet0/0/0 Interface

SNPA Address : d0d0-4b03-d3fc

IP Address : 10.0.15.1

IPV6 Link Local Address :

IPV6 Global Address(es) :

Csnp Timer Value : L12 10

Hello Timer Value : 10

DIS Hello Timer Value :

Hello Multiplier Value : 3

Cost : L1 10 L2 10

Ipv6 Cost : L1 10 L2 10

Retransmit Timer Value : L12 5

LSP-Throttle Timer : L12 50

Bandwidth-Value : Low 100000000 High 0

Static Bfd : NO

Dynamic Bfd : NO

Fast-Sense Rpr : NO

Extended-Circuit-Id Value : 0000000003

1. 配置IS-IS外部路由引入

在引入路由之前，先检查当前所有路由的学习情况，R1去往R4的路由呈现负载均衡的状态，数据包将会在GE0/0/1和S1/0/0之间均匀分布：

[R1]display isis route

Route information for ISIS(1)

-----------------------------

ISIS(1) Level-2 Forwarding Table

--------------------------------

IPV4 Destination IntCost ExtCost ExitInterface NextHop Flags

----------------------------------------------------------------------------

10.0.4.4/32 20 NULL GE0/0/1 10.0.13.3 A/-/-/-

S1/0/0 10.0.12.2

10.0.5.5/32 10 NULL GE0/0/0 10.0.15.5 A/-/-/-

10.0.12.0/24 10 NULL S1/0/0 Direct D/-/L/-

10.0.13.0/24 10 NULL GE0/0/1 Direct D/-/L/-

10.0.234.0/24 20 NULL S1/0/0 10.0.12.2 A/-/-/-

GE0/0/1 10.0.13.3

10.0.15.0/24 10 NULL GE0/0/0 Direct D/-/L/-

10.0.1.1/32 0 NULL Loop0 Direct D/-/L/-

10.0.2.2/32 10 NULL S1/0/0 10.0.12.2 A/-/-/-

10.0.3.3/32 10 NULL GE0/0/1 10.0.13.3 A/-/-/-

Flags: D-Direct, A-Added to URT, L-Advertised in LSPs, S-IGP Shortcut,

U-Up/Down Bit Set

[R1]display ip routing-table protocol isis

Route Flags: R - relay, D - download to fib

----------------------------------------------------------------------------

Public routing table : ISIS

Destinations : 5 Routes : 7

ISIS routing table status : <Active>

Destinations : 5 Routes : 7

Destination/Mask Proto Pre Cost Flags NextHop Interface

10.0.2.2/32 ISIS-L2 15 10 D 10.0.12.2 Serial1/0/0

10.0.3.3/32 ISIS-L2 15 10 D 10.0.13.3 GigabitEthernet0/0/1

10.0.4.4/32 ISIS-L2 15 20 D 10.0.13.3 GigabitEthernet0/0/1

ISIS-L2 15 20 D 10.0.12.2 Serial1/0/0

10.0.5.5/32 ISIS-L2 15 10 D 10.0.15.5 GigabitEthernet0/0/0

10.0.234.0/24 ISIS-L2 15 20 D 10.0.12.2 Serial1/0/0

ISIS-L2 15 20 D 10.0.13.3 GigabitEthernet0/0/1

ISIS routing table status : <Inactive>

Destinations : 0 Routes : 0

因为R2是LEVEL-1-2路由器，因此在两个level生成不同的路由，注意在level1会有默认路由的条目，指向空接口，R3和R2的情况相同：

[R2]display isis route

Route information for ISIS(1)

-----------------------------

ISIS(1) Level-1 Forwarding Table

--------------------------------

IPV4 Destination IntCost ExtCost ExitInterface NextHop Flags

----------------------------------------------------------------------------

0.0.0.0/0 10 NULL

10.0.4.4/32 10 NULL GE0/0/0 10.0.234.4 A/-/L/-

10.0.12.0/24 10 NULL S1/0/0 Direct D/-/L/-

10.0.13.0/24 20 NULL GE0/0/0 10.0.234.3 A/-/L/-

10.0.234.0/24 10 NULL GE0/0/0 Direct D/-/L/-

10.0.2.2/32 0 NULL Loop0 Direct D/-/L/-

10.0.3.3/32 10 NULL GE0/0/0 10.0.234.3 A/-/L/-

Flags: D-Direct, A-Added to URT, L-Advertised in LSPs, S-IGP Shortcut,

U-Up/Down Bit Set

ISIS(1) Level-2 Forwarding Table

--------------------------------

IPV4 Destination IntCost ExtCost ExitInterface NextHop Flags

----------------------------------------------------------------------------

10.0.4.4/32 20 NULL

10.0.5.5/32 20 NULL S1/0/0 10.0.12.1 A/-/-/-

10.0.12.0/24 10 NULL S1/0/0 Direct D/-/L/-

10.0.13.0/24 20 NULL

10.0.234.0/24 10 NULL GE0/0/0 Direct D/-/L/-

10.0.15.0/24 20 NULL S1/0/0 10.0.12.1 A/-/-/-

10.0.1.1/32 10 NULL S1/0/0 10.0.12.1 A/-/-/-

10.0.2.2/32 0 NULL Loop0 Direct D/-/L/-

10.0.3.3/32 10 NULL

Flags: D-Direct, A-Added to URT, L-Advertised in LSPs, S-IGP Shortcut,

U-Up/Down Bit Set

[R2]display ip routing-table protocol isis

Route Flags: R - relay, D - download to fib

----------------------------------------------------------------------------

Public routing table : ISIS

Destinations : 6 Routes : 6

ISIS routing table status : <Active>

Destinations : 6 Routes : 6

Destination/Mask Proto Pre Cost Flags NextHop Interface

10.0.1.1/32 ISIS-L2 15 10 D 10.0.12.1 Serial1/0/0

10.0.3.3/32 ISIS-L1 15 10 D 10.0.234.3 GigabitEthernet0/0/0

10.0.4.4/32 ISIS-L1 15 10 D 10.0.234.4 GigabitEthernet0/0/0

10.0.5.5/32 ISIS-L2 15 20 D 10.0.12.1 Serial1/0/0

10.0.13.0/24 ISIS-L1 5 20 D 10.0.234.3 GigabitEthernet0/0/0

10.0.15.0/24 ISIS-L2 15 20 D 10.0.12.1 Serial1/0/0

ISIS routing table status : <Inactive>

Destinations : 0 Routes : 0

[R3]display isis route

Route information for ISIS(1)

-----------------------------

ISIS(1) Level-1 Forwarding Table

--------------------------------

IPV4 Destination IntCost ExtCost ExitInterface NextHop Flags

----------------------------------------------------------------------------

0.0.0.0/0 10 NULL

10.0.4.4/32 10 NULL GE0/0/0 10.0.234.4 A/-/L/-

10.0.12.0/24 20 NULL GE0/0/0 10.0.234.2 A/-/L/-

10.0.13.0/24 10 NULL GE0/0/1 Direct D/-/L/-

10.0.234.0/24 10 NULL GE0/0/0 Direct D/-/L/-

10.0.2.2/32 10 NULL GE0/0/0 10.0.234.2 A/-/L/-

10.0.3.3/32 0 NULL Loop0 Direct D/-/L/-

Flags: D-Direct, A-Added to URT, L-Advertised in LSPs, S-IGP Shortcut,

U-Up/Down Bit Set

ISIS(1) Level-2 Forwarding Table

--------------------------------

IPV4 Destination IntCost ExtCost ExitInterface NextHop Flags

----------------------------------------------------------------------------

10.0.4.4/32 20 NULL

10.0.5.5/32 20 NULL GE0/0/1 10.0.13.1 A/-/-/-

10.0.12.0/24 20 NULL

10.0.13.0/24 10 NULL GE0/0/1 Direct D/-/L/-

10.0.234.0/24 10 NULL GE0/0/0 Direct D/-/L/-

10.0.15.0/24 20 NULL GE0/0/1 10.0.13.1 A/-/-/-

10.0.1.1/32 10 NULL GE0/0/1 10.0.13.1 A/-/-/-

10.0.2.2/32 10 NULL

10.0.3.3/32 0 NULL Loop0 Direct D/-/L/-

Flags: D-Direct, A-Added to URT, L-Advertised in LSPs, S-IGP Shortcut,

U-Up/Down Bit Set

[R3]display ip routing-table protocol isis

Route Flags: R - relay, D - download to fib

----------------------------------------------------------------------------

Public routing table : ISIS

Destinations : 6 Routes : 6

ISIS routing table status : <Active>

Destinations : 6 Routes : 6

Destination/Mask Proto Pre Cost Flags NextHop Interface

10.0.1.1/32 ISIS-L2 15 10 D 10.0.13.1 GigabitEthernet0/0/1

10.0.2.2/32 ISIS-L1 15 10 D 10.0.234.2 GigabitEthernet0/0/0

10.0.4.4/32 ISIS-L1 15 10 D 10.0.234.4 GigabitEthernet0/0/0

10.0.5.5/32 ISIS-L2 15 20 D 10.0.13.1 GigabitEthernet0/0/1

10.0.12.0/24 ISIS-L1 15 20 D 10.0.234.2 GigabitEthernet0/0/0

10.0.15.0/24 ISIS-L2 15 20 D 10.0.13.1 GigabitEthernet0/0/1

ISIS routing table status : <Inactive>

Destinations : 0 Routes : 0

由于R4是L1路由器，只能和同区域的L1或者LEVEL-1-2路由器建立邻居，并且默认情况下L1路由器无法学到L2的路由信息，只能够通过默认路由访问外部，R4可以看到两条默认路由指向R2和R3，呈现负载均衡。

[R4]display isis route

Route information for ISIS(1)

-----------------------------

ISIS(1) Level-1 Forwarding Table

--------------------------------

IPV4 Destination IntCost ExtCost ExitInterface NextHop Flags

----------------------------------------------------------------------------

0.0.0.0/0 10 NULL GE0/0/0 10.0.234.3 A/-/-/-

GE0/0/0 10.0.234.2

10.0.4.4/32 0 NULL Loop0 Direct D/-/L/-

10.0.12.0/24 20 NULL GE0/0/0 10.0.234.2 A/-/-/-

10.0.13.0/24 20 NULL GE0/0/0 10.0.234.3 A/-/-/-

10.0.234.0/24 10 NULL GE0/0/0 Direct D/-/L/-

10.0.2.2/32 10 NULL GE0/0/0 10.0.234.2 A/-/-/-

10.0.3.3/3 10 NULL GE0/0/0 10.0.234.3 A/-/-/-

Flags: D-Direct, A-Added to URT, L-Advertised in LSPs, S-IGP Shortcut,

U-Up/Down Bit Set

[R4]display ip routing protocol isis

Route Flags: R - relay, D - download to fib

----------------------------------------------------------------------------

Public routing table : ISIS

Destinations : 5 Routes : 6

ISIS routing table status : <Active>

Destinations : 5 Routes : 6

Destination/Mask Proto Pre Cost Flags NextHop Interface

0.0.0.0/0 ISIS-L1 15 10 D 10.0.234.3 GigabitEthernet0/0/0

ISIS-L1 15 10 D 10.0.234.2 GigabitEthernet0/0/0

10.0.2.2/32 ISIS-L1 15 10 D 10.0.234.2 GigabitEthernet0/0/0

10.0.3.3/32 ISIS-L1 15 10 D 10.0.234.3 GigabitEthernet0/0/0

10.0.12.0/24 ISIS-L1 15 20 D 10.0.234.2 GigabitEthernet0/0/0

10.0.13.0/24 ISIS-L1 15 20 D 10.0.234.3 GigabitEthernet0/0/0

ISIS routing table status : <Inactive>

Destinations : 0 Routes : 0

R5在引入外部路由前，路由学习情况：

[R5]display isis route

Route information for ISIS(1)

-----------------------------

ISIS(1) Level-2 Forwarding Table

--------------------------------

IPV4 Destination IntCost ExtCost ExitInterface NextHop Flags

10.0.4.4/32 30 NULL GE0/0/0 10.0.15.1 A/-/-/-

10.0.5.5/32 0 NULL Loop0 Direct D/-/L/-

10.0.12.0/24 20 NULL GE0/0/0 10.0.15.1 A/-/-/-

10.0.13.0/24 20 NULL GE0/0/0 10.0.15.1 A/-/-/-

10.0.234.0/24 30 NULL GE0/0/0 10.0.15.1 A/-/-/-

10.0.15.0/24 10 NULL GE0/0/0 Direct D/-/L/-

10.0.1.1/32 10 NULL GE0/0/0 10.0.15.1 A/-/-/-

10.0.2.2/32 20 NULL GE0/0/0 10.0.15.1 A/-/-/-

10.0.3.3/32 20 NULL GE0/0/0 10.0.15.1 A/-/-/-

Flags: D-Direct, A-Added to URT, L-Advertised in LSPs, S-IGP Shortcut,

U-Up/Down Bit Set

[R5]display ip routing-table protocol isis

Route Flags: R - relay, D - download to fib

----------------------------------------------------------------------------

Public routing table : ISIS

Destinations : 7 Routes : 7

ISIS routing table status : <Active>

Destinations : 7 Routes : 7

Destination/Mask Proto Pre Cost Flags NextHop Interface

10.0.1.1/32 ISIS-L2 15 10 D 10.0.15.1 GigabitEthernet0/0/0

10.0.2.2/32 ISIS-L2 15 20 D 10.0.15.1 GigabitEthernet0/0/0

10.0.3.3/32 ISIS-L2 15 20 D 10.0.15.1 GigabitEthernet0/0/0

10.0.4.4/32 ISIS-L2 15 30 D 10.0.15.1 GigabitEthernet0/0/0

10.0.12.0/24 ISIS-L2 15 20 D 10.0.15.1 GigabitEthernet0/0/0

10.0.13.0/24 ISIS-L2 15 20 D 10.0.15.1 GigabitEthernet0/0/0

10.0.234.0/24 ISIS-L2 15 30 D 10.0.15.1 GigabitEthernet0/0/0

ISIS routing table status : <Inactive>

Destinations : 0 Routes : 0

在R5上创建新的LoopBack口，并引入到isis进程：

[R5]interface LoopBack 1

[R5-LoopBack1]ip address 192.168.1.1 24

[R5-LoopBack1]quit

[R5]interface LoopBack 2

[R5-LoopBack2]ip address 192.168.2.1 24

[R5-LoopBack2]quit

[R5]interface LoopBack 3

[R5-LoopBack3]ip address 192.168.3.1 24

[R5-LoopBack3]quit

[R5]isis

[R5-isis-1]import-route direct level-2

[R5-isis-1]quit

在R5上直连路由引入level-2，查看效果：

[R5]display isis route

Route information for ISIS(1)

-----------------------------

ISIS(1) Level-2 Forwarding Table

--------------------------------

IPV4 Destination IntCost ExtCost ExitInterface NextHop Flags

----------------------------------------------------------------------------

10.0.4.4/32 30 NULL GE0/0/0 10.0.15.1 A/-/-/-

10.0.5.5/32 0 NULL Loop0 Direct D/-/L/-

10.0.12.0/24 20 NULL GE0/0/0 10.0.15.1 A/-/-/-

10.0.13.0/24 20 NULL GE0/0/0 10.0.15.1 A/-/-/-

10.0.234.0/24 30 NULL GE0/0/0 10.0.15.1 A/-/-/-

10.0.15.0/24 10 NULL GE0/0/0 Direct D/-/L/-

10.0.1.1/32 10 NULL GE0/0/0 10.0.15.1 A/-/-/-

10.0.2.2/32 20 NULL GE0/0/0 10.0.15.1 A/-/-/-

10.0.3.3/32 20 NULL GE0/0/0 10.0.15.1 A/-/-/-

Flags: D-Direct, A-Added to URT, L-Advertised in LSPs, S-IGP Shortcut,

U-Up/Down Bit Set

ISIS(1) Level-2 Redistribute Table

----------------------------------

Type IPV4 Destination IntCost ExtCost Tag

----------------------------------------------------------------------------

D 192.168.1.0/24 0 0

D 192.168.2.0/24 0 0

D 192.168.3.0/24 0 0

Type: D-Direct, I-ISIS, S-Static, O-OSPF, B-BGP, R-RIP, U-UNR

此时在R4上再次查看路由表，发现并没有变化，原因是在默认情况下，L2路由不会渗透进入L1路由器，但通过默认路由，R4可访问 192.168.1.0/24、192.168.2.0/24和192.168.3.0/24。

[R4]display ip routing-table protocol isis

Route Flags: R - relay, D - download to fib

----------------------------------------------------------------------------

Public routing table : ISIS

Destinations : 5 Routes : 6

ISIS routing table status : <Active>

Destinations : 5 Routes : 6

Destination/Mask Proto Pre Cost Flags NextHop Interface

0.0.0.0/0 ISIS-L1 15 10 D 10.0.234.3 GigabitEthernet0/0/0

ISIS-L1 15 10 D 10.0.234.2 GigabitEthernet0/0/0

10.0.2.2/32 ISIS-L1 15 10 D 10.0.234.2 GigabitEthernet0/0/0

10.0.3.3/32 ISIS-L1 15 10 D 10.0.234.3 GigabitEthernet0/0/0

10.0.12.0/24 ISIS-L1 15 20 D 10.0.234.2 GigabitEthernet0/0/0

10.0.13.0/24 ISIS-L1 15 20 D 10.0.234.3 GigabitEthernet0/0/0

ISIS routing table status : <Inactive>

Destinations : 0 Routes : 0

[R4]ping -c 1 192.168.1.1

PING 192.168.1.1: 56 data bytes, press CTRL\_C to break

Reply from 192.168.1.1: bytes=56 Sequence=1 ttl=253 time=14 ms

--- 192.168.1.1 ping statistics ---

1 packet(s) transmitted

1 packet(s) received

0.00% packet loss

round-trip min/avg/max = 14/14/14 ms

[R4]ping -c 1 192.168.2.1

PING 192.168.2.1: 56 data bytes, press CTRL\_C to break

Reply from 192.168.2.1: bytes=56 Sequence=1 ttl=253 time=13 ms

--- 192.168.2.1 ping statistics ---

1 packet(s) transmitted

1 packet(s) received

0.00% packet loss

round-trip min/avg/max = 13/13/13 ms

[R4]ping -c 1 192.168.3.1

PING 192.168.3.1: 56 data bytes, press CTRL\_C to break

Reply from 192.168.3.1: bytes=56 Sequence=1 ttl=253 time=1 ms

--- 192.168.3.1 ping statistics ---

1 packet(s) transmitted

1 packet(s) received

0.00% packet loss

round-trip min/avg/max = 1/1/1 ms

1. 修改IS-IS接口Cost值

默认情况下，IS-IS接口cost值为10，不会基于带宽自动计算，对于R1来说，去往R4的流量会在R2和R3上负载均衡，但由于R1和R2之间使用Series接口，带宽较小，容易出现瓶颈，因此可以通过修改相应的cost值来控制R1的选路。

增大出口的cost值：

[R1]interface Serial 1/0/0

[R1-Serial1/0/0]isis cost 15

[R1-Serial1/0/0]quit

[R1]display isis route

Route information for ISIS(1)

-----------------------------

ISIS(1) Level-2 Forwarding Table

--------------------------------

IPV4 Destination IntCost ExtCost ExitInterface NextHop Flags

----------------------------------------------------------------------------

10.0.4.4/32 20 NULL GE0/0/1 10.0.13.3 A/-/-/-

10.0.5.5/32 10 NULL GE0/0/0 10.0.15.5 A/-/-/-

192.168.1.0/24 10 0 GE0/0/0 10.0.15.5 A/-/-/-

10.0.12.0/24 15 NULL S1/0/0 Direct D/-/L/-

192.168.2.0/24 10 0 GE0/0/0 10.0.15.5 A/-/-/-

10.0.13.0/24 10 NULL GE0/0/1 Direct D/-/L/-

192.168.3.0/24 10 0 GE0/0/0 10.0.15.5 A/-/-/-

10.0.234.0/24 20 NULL GE0/0/1 10.0.13.3 A/-/-/-

10.0.15.0/24 10 NULL GE0/0/0 Direct D/-/L/-

10.0.1.1/32 0 NULL Loop0 Direct D/-/L/-

10.0.2.2/32 15 NULL S1/0/0 10.0.12.2 A/-/-/-

10.0.3.3/32 10 NULL GE0/0/1 10.0.13.3 A/-/-/-

Flags: D-Direct, A-Added to URT, L-Advertised in LSPs, S-IGP Shortcut,

U-Up/Down Bit Set

可以看到在R1上负载均衡已经消失，去往R4的流量将从以太网接口转发。

1. 配置IS-IS路由渗透

观察R4的数据转发，由于R4对Level-2网络状况一无所知，因此使用负载均衡转发数据到R2和R3，如果我们希望R4不使用R2到R1之间的链路，可以通过路由渗透将Level-2的路由引入到Level-1中，通过路由最长匹配选路，从R3转发去往R5的数据包。

测试tracert之前，需要在R5上开启端口不可达的响应，默认是关闭的，如果不开启，则最后一跳会超时。

在开启前：

[R4]tracert 192.168.1.1

traceroute to 192.168.1.1(192.168.1.1), max hops: 30 ,packet length: 40,press CTRL\_C to break

1 10.0.234.2 2 ms 10.0.234.3 2 ms 10.0.234.2 2 ms

2 10.0.13.1 11 ms 10.0.12.1 9 ms 10.0.13.1 11 ms

3 \* \* \*

在R5上开启后：

[R5]icmp port-unreachable send

[R4]tracert 192.168.1.1

traceroute to 192.168.1.1(192.168.1.1), max hops: 30 ,packet length: 40,press CTRL\_C to break

1 10.0.234.2 2 ms 10.0.234.3 2 ms 10.0.234.2 2 ms

2 10.0.13.1 2 ms 10.0.12.1 9 ms 10.0.13.1 1 ms

3 192.168.1.1 8 ms 1 ms 9 ms

可以看到每次发出的tracert包会在两个下一跳地址负载均衡到达R5，此时我们在R3开启路由渗透，使得R3为更优的下一跳：

[R3]isis

[R3-isis-1]import-route isis level-2 into level-1

[R3-isis-1]quit

[R4]display isis route

Route information for ISIS(1)

-----------------------------

ISIS(1) Level-1 Forwarding Table

--------------------------------

IPV4 Destination IntCost ExtCost ExitInterface NextHop Flags

----------------------------------------------------------------------------

0.0.0.0/0 10 NULL GE0/0/0 10.0.234.3 A/-/-/-

GE0/0/0 10.0.234.2

10.0.4.4/32 0 NULL Loop0 Direct D/-/L/-

10.0.5.5/32 30 NULL GE0/0/0 10.0.234.3 A/-/-/U

192.168.1.0/24 10 20 GE0/0/0 10.0.234.3 A/-/-/U

10.0.12.0/24 20 NULL GE0/0/0 10.0.234.2 A/-/-/-

192.168.2.0/24 10 20 GE0/0/0 10.0.234.3 A/-/-/U

10.0.13.0/24 20 NULL GE0/0/0 10.0.234 A/-/-/-

192.168.3.0/24 10 20 GE0/0/0 10.0.234.3 A/-/-/U

10.0.234.0/24 10 NULL GE0/0/0 Direct D/-/L/-

10.0.15.0/24 30 NULL GE0/0/0 10.0.234.3 A/-/-/U

10.0.1.1/32 20 NULL GE0/0/0 10.0.234.3 A/-/-/U

10.0.2.2/32 10 NULL GE0/0/0 10.0.234.2 A/-/-/-

10.0.3.3/32 10 NULL GE0/0/0 10.0.234.3 A/-/-/-

Flags: D-Direct, A-Added to URT, L-Advertised in LSPs, S-IGP Shortcut,

U-Up/Down Bit Set

[R4]display ip routing-table protocol isis

Route Flags: R - relay, D - download to fib

----------------------------------------------------------------------------

Public routing table : ISIS

Destinations : 11 Routes : 12

ISIS routing table status : <Active>

Destinations : 11 Routes : 12

Destination/Mask Proto Pre Cost Flags NextHop Interface

0.0.0.0/0 ISIS-L1 15 10 D 10.0.234.3 GigabitEthernet0/0/0

ISIS-L1 15 10 D 10.0.234.2 GigabitEthernet0/0/0

10.0.1.1/32 ISIS-L1 15 20 D 10.0.234.3 GigabitEthernet0/0/0

10.0.2.2/32 ISIS-L1 15 10 D 10.0.234.2 GigabitEthernet0/0/0

10.0.3.3/32 ISIS-L1 15 10 D 10.0.234.3 GigabitEthernet0/0/0

10.0.5.5/32 ISIS-L1 15 30 D 10.0.234.3 GigabitEthernet0/0/0

10.0.12.0/24 ISIS-L1 15 20 D 10.0.234.2 GigabitEthernet0/0/0

10.0.13.0/24 ISIS-L1 15 20 D 10.0.234.3 GigabitEthernet0/0/0

10.0.15.0/24 ISIS-L1 15 30 D 10.0.234.3 GigabitEthernet0/0/0

192.168.1.0/24 ISIS-L1 15 94 D 10.0.234.3 GigabitEthernet0/0/0

192.168.2.0/24 ISIS-L1 15 94 D 10.0.234.3 GigabitEthernet0/0/0

192.168.3.0/24 ISIS-L1 15 94 D 10.0.234.3 GigabitEthernet0/0/0

ISIS routing table status : <Inactive>

Destinations : 0 Routes : 0

[R4]tracert 192.168.1.1

traceroute to 192.168.1.1(192.168.1.1), max hops: 30 ,packet length: 40,press CTRL\_C to break

1 10.0.234.3 2 ms 1 ms 1 ms

2 10.0.13.1 2 ms 2 ms 2 ms

3 192.168.1.1 1 ms 1 ms 2 ms

最终，通过tracert测试验证了路由渗透对IS-IS选路效果的影响。

配置文件参考

<R1>**display current-configuration**

[V200R007C00SPC600]

#

sysname R1

#

isis 1

is-level level-2

network-entity 49.0002.0000.0000.0001.00

#

interface Serial1/0/0

link-protocol ppp

ip address 10.0.12.1 255.255.255.0

isis enable 1

isis cost 15

#

interface GigabitEthernet0/0/0

ip address 10.0.15.1 255.255.255.0

isis enable 1

isis circuit-type p2p

#

interface GigabitEthernet0/0/1

ip address 10.0.13.1 255.255.255.0

isis enable 1

#

interface LoopBack0

ip address 10.0.1.1 255.255.255.255

isis enable 1

#

return

<R2>**display current-configuration**

[V200R007C00SPC600]

#

sysname R2

#

isis 1

network-entity 49.0001.0000.0000.0002.00

#

interface Serial1/0/0

link-protocol ppp

ip address 10.0.12.2 255.255.255.0

isis enable 1

#

interface GigabitEthernet0/0/0

ip address 10.0.234.2 255.255.255.0

isis enable 1

#

interface LoopBack0

ip address 10.0.2.2 255.255.255.255

isis enable 1

#

return

<R3>**display current-configuration**

[V200R007C00SPC600]

#

sysname R3

#

isis 1

network-entity 49.0001.0000.0000.0003.00

import-route isis level-2 into level-1

#

interface GigabitEthernet0/0/0

ip address 10.0.234.3 255.255.255.0

isis enable 1

#

interface GigabitEthernet0/0/1

ip address 10.0.13.3 255.255.255.0

isis enable 1

#

interface LoopBack0

ip address 10.0.3.3 255.255.255.255

isis enable 1

#

return

<R4>**display current-configuration**

[V200R007C00SPC600]

#

sysname R4

#

isis 1

is-level level-1

network-entity 49.0001.0000.0000.0004.00

#

interface GigabitEthernet0/0/0

ip address 10.0.234.4 255.255.255.0

isis enable 1

isis dis-priority 120

#

interface LoopBack0

ip address 10.0.4.4 255.255.255.255

isis enable 1

#

return

<R5>**display current-configuration**

[V200R007C00SPC600]

#

sysname R5

#

icmp port-unreachable send

#

isis 1

is-level level-2

network-entity 49.0002.0000.0000.0005.00

import-route direct

#

interface GigabitEthernet0/0/0

ip address 10.0.15.5 255.255.255.0

isis enable 1

isis circuit-type p2p

#

interface LoopBack0

ip address 10.0.5.5 255.255.255.255

isis enable 1

#

interface LoopBack1

ip address 192.168.1.1 255.255.255.0

#

interface LoopBack2

ip address 192.168.2.1 255.255.255.0

#

interface LoopBack3

ip address 192.168.3.1 255.255.255.0

#

return

第三章 BGP协议特性与配置

实验 3-1 IBGP与EBGP

学习目的

* 掌握区域内部BGP的配置方法
* 掌握多区域BGP的配置方法
* 观察BGP的邻居表和数据库
* 掌握BGP更新源的配置方法
* 掌握EBGP多跳的配置方法
* 观察IBGP和EBGP中路由的下一跳的变化
* 掌握IBGP中下一跳的配置
* 掌握BGP的Network命令的配置方法

## **拓扑图**

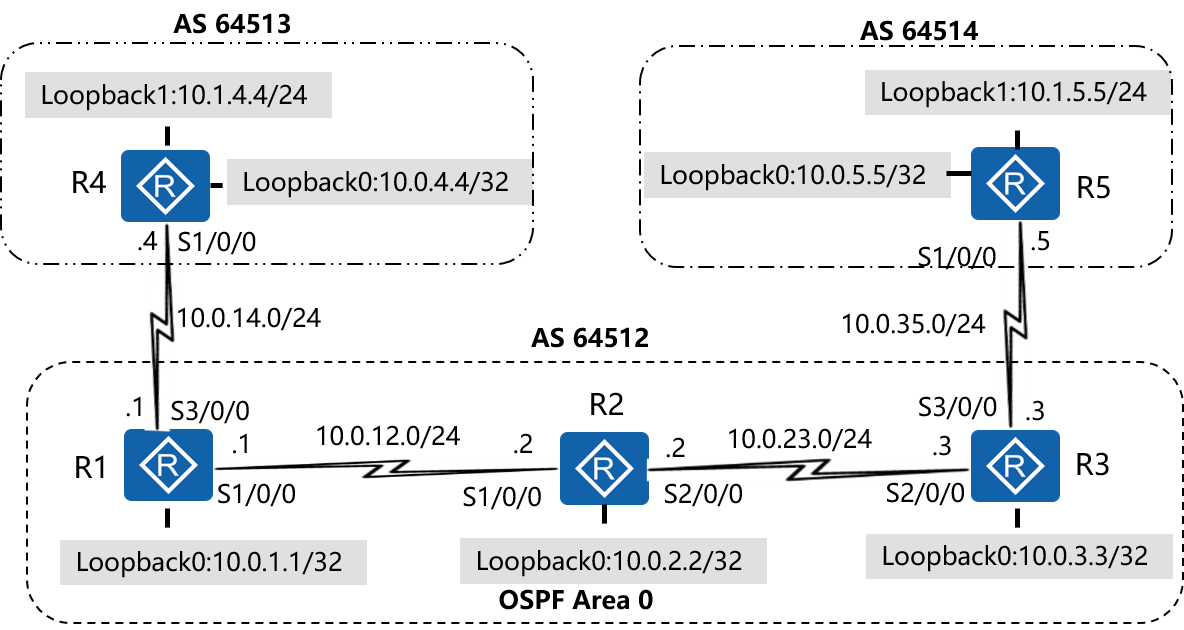


图3-1 IBGP与EBGP

## **场景**

你是公司的网络管理员。公司的网络采用了BGP协议作为路由协议。公司的网络由多个自治系统组成，不同的分支机构使用了不同的AS号，现在你需要完成公司网络的搭建工作。在公司总部使用了OSPF作为IGP，公司内部不同分支机构使用的是私有的BGP AS号。在完成网络搭建以后，你还需要观察BGP路由信息的传递。

学习任务

1. 基础配置与IP编址

给所有路由器配置IP地址和掩码，其中R4和R5的loopback 1接口掩码为24位，模拟用户网络。

<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 Serial 3/0/0

[R1-Serial3/0/0]ip address 10.0.14.1 24

[R1-Serial3/0/0]quit

[R1]interface LoopBack 0

[R1-LoopBack0]ip address 10.0.1.1 32

[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 LoopBack 0

[R2-LoopBack0]ip address 10.0.2.2 32

<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 32

<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]quit

[R3]interface LoopBack 0

[R4-LoopBack0]ip address 10.0.4.4 32

<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

[R3]interface LoopBack 0

[R5-LoopBack0]ip address 10.0.5.5 32

测试各直连链路的连通性。

<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=34 ms

--- 10.0.12.2 ping statistics ---

1 packet(s) transmitted

1 packet(s) received

0.00% packet loss

round-trip min/avg/max = 34/34/34 ms

<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=40 ms

--- 10.0.14.4 ping statistics ---

1 packet(s) transmitted

1 packet(s) received

0.00% packet loss

round-trip min/avg/max = 40/40/40 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=33 ms

--- 10.0.23.2 ping statistics ---

1 packet(s) transmitted

1 packet(s) received

0.00% packet loss

round-trip min/avg/max = 33/33/33 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=35 ms

--- 10.0.35.5 ping statistics ---

1 packet(s) transmitted

1 packet(s) received

0.00% packet loss

round-trip min/avg/max = 35/35/35 ms

显示直连联络连通性正常。

1. 配置区域内IGP

在AS 64512中使用OSPF作为IGP，将Loopback 0连接的网段发布进OSPF。R1的S1/0/0连接的网段运行OSPF。

[R1]router id 10.0.1.1

[R1]ospf 1

[R1-ospf-1]area 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 10.0.1.1 0.0.0.0

[R1-ospf-1-area-0.0.0.0]quit

[R1-ospf-1]quit

R2的S1/0/0和S2/0/0连接的网段运行OSPF。

[R2]router id 10.0.2.2

[R2]ospf 1

[R2-ospf-1]area 0

[R2-ospf-1-area-0.0.0.0]network 10.0.12.2 0.0.0.0

[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]quit

R3的S2/0/0连接的网段运行OSPF。

[R3]router id 10.0.3.3

[R3]ospf 1

[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]quit

注意在使用network命令时，通配符掩码使用0.0.0.0。

配置完成后察看OSPF的邻居关系是否建立。

[R2]display ospf peer

OSPF Process 1 with Router ID 10.0.2.2

Neighbors

Area 0.0.0.0 interface 10.0.12.2(Serial1/0/0)'s neighbors

Router ID: 10.0.1.1 Address: 10.0.12.1

State: Full Mode:Nbr is Slave Priority: 1

DR: None BDR: None MTU: 0

Dead timer due in 37 sec

Retrans timer interval: 5

Neighbor is up for 00:01:05

Authentication Sequence: [ 0 ]

Neighbors

Area 0.0.0.0 interface 10.0.23.2(Serial2/0/0)'s neighbors

Router ID: 10.0.3.3 Address: 10.0.23.3

State: Full Mode:Nbr is Master Priority: 1

DR: None BDR: None MTU: 0

Dead timer due in 33 sec

Retrans timer interval: 5

Neighbor is up for 00:00:19

Authentication Sequence: [ 0 ]

查看所有路由器的路由表。检查是否学习到对端设备Loopback接口网段的路由。

[R1]display ip routing-table

Route Flags: R - relay, D - download to fib

----------------------------------------------------------------------------

Routing Tables: Public

Destinations : 15 Routes : 15

Destination/Mask Proto Pre Cost Flags NextHop Interface

10.0.1.1/32 Direct 0 0 D 127.0.0.1 LoopBack0

10.0.2.2/32 OSPF 10 1562 D 10.0.12.2 Serial1/0/0

10.0.3.3/32 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 Serial1/0/0

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 Serial1/0/0

10.0.14.0/24 Direct 0 0 D 10.0.14.1 Serial3/0/0

10.0.14.1/32 Direct 0 0 D 127.0.0.1 Serial3/0/0

10.0.14.4/32 Direct 0 0 D 10.0.14.4 Serial3/0/0

10.0.14.255/32 Direct 0 0 D 127.0.0.1 Serial3/0/0

10.0.23.0/24 OSPF 10 3124 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

127.255.255.255/32Direct 0 0 D 127.0.0.1 InLoopBack0

255.255.255.255/3 Direct 0 0 D 127.0.0.1 InLoopBack0

[R2]display ip routing-table

Route Flags: R - relay, D - download to fib

----------------------------------------------------------------------------

Routing Tables: Public

Destinations : 15 Routes : 15

Destination/Mask Proto Pre Cost Flags NextHop Interface

10.0.1.1/32 OSPF 10 1562 D 10.0.12.1 Serial1/0/0

10.0.2.2/32 Direct 0 0 D 127.0.0.1 LoopBack0

10.0.3.3/32 OSPF 10 1562 D 10.0.23.3 Serial2/0/0

10.0.12.0/24 Direct 0 0 D 10.0.12.2 Serial1/0/0

10.0.12.1/32 Direct 0 0 D 10.0.12.1 Serial1/0/0

10.0.12.2/32 Direct 0 0 D 127.0.0.1 Serial1/0/0

10.0.12.255/32 Direct 0 0 D 127.0.0.1 Serial1/0/0

10.0.23.0/24 Direct 0 0 D 10.0.23.2 Serial2/0/0

10.0.23.2/32 Direct 0 0 D 127.0.0.1 Serial2/0/0

10.0.23.3/32 Direct 0 0 D 10.0.23.3 Serial2/0/0

10.0.23.255/32 Direct 0 0 D 127.0.0.1 Serial2/0/0

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

[R3]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

10.0.1.1/32 OSPF 10 3124 D 10.0.23.2 Serial2/0/0

10.0.2.2/32 OSPF 10 1562 D 10.0.23.2 Serial2/0/0

10.0.3.3/32 Direct 0 0 D 127.0.0.1 LoopBack0

10.0.12.0/24 OSPF 10 3124 D 10.0.23.2 Serial2/0/0

10.0.23.0/24 Direct 0 0 D 10.0.23.3 Serial2/0/0

10.0.23.2/32 Direct 0 0 D 10.0.23.2 Serial2/0/0

10.0.23.3/32 Direct 0 0 D 127.0.0.1 Serial2/0/0

10.0.23.255/32 Direct 0 0 D 127.0.0.1 Serial2/0/0

10.0.35.0/24 Direct 0 0 D 10.0.35.3 Serial3/0/0

10.0.35.3/32 Direct 0 0 D 127.0.0.1 Serial3/0/0

10.0.35.5/32 Direct 0 0 D 10.0.35.5 Serial3/0/0

10.0.35.255/32 Direct 0 0 D 127.0.0.1 Serial3/0/0

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

127.255.255.255/32Direct 0 0 D 127.0.0.1 InLoopBack0

255.255.255.255/32Direct 0 0 D 127.0.0.1 InLoopBack0

从R1，R2，R3的路由表中，可以看到学习每一台路由器都能够学到其他2台路由器的loopback 0接口连接的网段的路由。

1. 建立IBGP对等体

在R1、R2、R3上配置IBGP全互联。使用Loopback0地址作为更新源。

[R1]bgp 64512

[R1-bgp]peer 10.0.2.2 as-number 64512

[R1-bgp]peer 10.0.2.2 connect-interface LoopBack 0

[R1-bgp]peer 10.0.3.3 as-number 64512

[R1-bgp]peer 10.0.3.3 connect-interface LoopBack 0

[R1-bgp]quit

[R2]bgp 64512

[R2-bgp]peer 10.0.1.1 as-number 64512

[R2-bgp]peer 10.0.1.1 connect-interface loopback 0

[R2-bgp]peer 10.0.3.3 as-number 64512

[R2-bgp]peer 10.0.3.3 connect-interface LoopBack 0

[R2-bgp]quit

[R3]bgp 64512

[R3-bgp]peer 10.0.1.1 as-number 64512

[R3-bgp]peer 10.0.1.1 connect-interface loopback 0

[R3-bgp]peer 10.0.2.2 as-number 64512

[R3-bgp]peer 10.0.2.2 connect-interface LoopBack 0

[R3-bgp]quit

使用**display tcp status**查看TCP端口连接状态。

[R2]display tcp status

TCPCB Tid/Soid Local Add:port Foreign Add:port VPNID State

37a32f14 76 /1 0.0.0.0:80 0.0.0.0:0 23553 Listening

37a33b34 239/2 0.0.0.0:179 10.0.1.1:0 0 Listening

39052914 239/6 0.0.0.0:179 10.0.3.3:0 0 Listening

37a3321c 76 /3 0.0.0.0:443 0.0.0.0:0 23553 Listening

39052c1c 239/11 10.0.2.2:179 10.0.3.3:54086 0 Established

3905260c 239/5 10.0.2.2:61635 10.0.1.1:179 0 Established

从表项中我们可以观察到Local Add为10.0.2.2（即为R2的Loopback0接口地址），端口号为179（BGP协议的TCP端口号）。与10.0.3.3和10.0.1.1的状态已经为Established，说明R2和R1，R3的TCP连接已建立。

使用**display bgp peer**察看各路由器BGP邻居关系状态。

[R1]display bgp peer

BGP local router ID : 10.0.1.1

Local AS number : 64512

Total number of peers : 2 Peers in established state : 2

Peer V AS MsgRcvd MsgSent OutQ Up/Down State PrefRcv

10.0.2.2 4 64512 273 277 0 02:15:53 Established 0

10.0.3.3 4 64512 276 276 0 02:15:53 Established 0

[R2]display bgp peer

BGP local router ID : 10.0.2.2

Local AS number : 64512

Total number of peers : 2 Peers in established state : 2

Peer V AS MsgRcvd MsgSent OutQ Up/Down State PrefRcv

10.0.1.1 4 64512 38 38 0 00:18:02 Established 0

10.0.3.3 4 64512 1000 1000 0 16:38:38 Established 0

[R3]display bgp peer

BGP local router ID : 10.0.3.3

Local AS number : 64512

Total number of peers : 2 Peers in established state : 2

Peer V AS MsgRcvd MsgSent OutQ Up/Down State PrefRcv

10.0.1.1 4 64512 39 39 0 00:18:35 Established 0

10.0.2.2 4 64512 1001 1001 0 16:39:11 Established 0

可以看到3台路由器之间的BGP邻居关系处于Established状态，说明邻居关系已建立。

在R1上在BGP进程下使用**timer**修改BGP的keep alive时间为30秒，hold时间为90秒。观察R1与R2的对等体关系建立是否有问题，使用**display bgp peer verbose**命令观察建立以后协商的间隔时间是多少。

[R1-bgp] bgp 64512

[R1-bgp] timer keepalive 30 hold 90

Warning: Changing the parameter in this command resets the peer session. Continue?[Y/N]:y

[R1-bgp]quit

注意：修改此参数将引起bgp邻居重启。

[R2]display bgp peer verbose

BGP Peer is 10.0.1.1, remote AS 64512

Type: IBGP link

BGP version 4, Remote router ID 10.0.1.1

Update-group ID: 1

BGP current state: Established, Up for 00h07m19s

BGP current event: KATimerExpired

BGP last state: OpenConfirm

BGP Peer Up count: 2

Received total routes: 0

Received active routes total: 0

Advertised total routes: 0

Port: Local - 50117 Remote - 179

Configured: Connect-retry Time: 32 sec

Configured: Active Hold Time: 180 sec Keepalive Time:60 sec

Received : Active Hold Time: 90 sec

Negotiated: Active Hold Time: 90 sec Keepalive Time:30 sec

Peer optional capabilities:

Peer supports bgp multi-protocol extension

Peer supports bgp route refresh capability

Peer supports bgp 4-byte-as capability

Address family IPv4 Unicast: advertised and received

Received: Total 16 messages

Update messages 0

Open messages 1

KeepAlive messages 15

Notification messages 0

Refresh messages 0

Sent: Total 16 messages

Update messages 0

Open messages 1

KeepAlive messages 15

Notification messages 0

Refresh messages 0

Authentication type configured: None

Last keepalive received: 2011/12/07 08:33:52

Minimum route advertisement interval is 15 seconds

Optional capabilities:

Route refresh capability has been enabled

4-byte-as capability has been enabled

Connect-interface has been configured

Peer Preferred Value: 0

Routing policy configured:

No routing policy is configured

BGP Peer is 10.0.3.3, remote AS 64512

Type: IBGP link

BGP version 4, Remote router ID 10.0.3.3

Update-group ID: 1

BGP current state: Established, Up for 16h28m14s

BGP current event: RecvKeepalive

BGP last state: OpenConfirm

BGP Peer Up count: 1

Received total routes: 0

Received active routes total: 0

Advertised total routes: 0

Port: Local - 179 Remote - 49663

Configured: Connect-retry Time: 32 sec

Configured: Active Hold Time: 180 sec Keepalive Time:60 sec

Received : Active Hold Time: 180 sec

Negotiated: Active Hold Time: 180 sec Keepalive Time:60 sec

Peer optional capabilities:

Peer supports bgp multi-protocol extension

Peer supports bgp route refresh capability

Peer supports bgp 4-byte-as capability

Address family IPv4 Unicast: advertised and received

Received: Total 990 messages

Update messages 0

Open messages 1

KeepAlive messages 989

Notification messages 0

Refresh messages 0

Sent: Total 990 messages

Update messages 0

Open messages 1

KeepAlive messages 989

Notification messages 0

Refresh messages 0

Authentication type configured: None

Last keepalive received: 2011/12/07 08:34:17

Minimum route advertisement interval is 15 seconds

Optional capabilities:

Route refresh capability has been enabled

4-byte-as capability has been enabled

Connect-interface has been configured

Peer Preferred Value: 0

Routing policy configured:

No routing policy is configured

可以看到在R2上默认的配置参数Active Hold Time为180s，Keepalive Time为60s。

当R1的参数修改之后，R2收到数据包的Active Hold Time为90s。协商的参数取值数值小的参数，所以R2与R1的协商的结果Active Hold Time为90s，keepalive Time为30s，而R3的参数仍然为默认参数。

R2和R3一样，所以协商的结果配置参数和协商参数一致，Active Hold Time为180s，Keepalive Time为60s。

1. 配置EBGP对等体

在R4上配置BGP，本地AS号为64513，与R1建立EBGP对等体关系。在建立对等体关系时，指定更新源为Loopback 0接口的地址，并指定**ebgp-max-hop**为2。添加到对端Loopback 0接口地址的32位的静态路由，使之能正常建立对等体关系。

[R1]ip route-static 10.0.4.4 32 10.0.14.4

[R4]ip route-static 10.0.1.1 32 10.0.14.1

[R1]bgp 64512

[R1-bgp]peer 10.0.4.4 as-number 64513

[R1-bgp]peer 10.0.4.4 ebgp-max-hop 2

[R1-bgp]peer 10.0.4.4 connect-interface LoopBack0

[R1-bgp]quit

[R4]router id 10.0.4.4

[R4]bgp 64513

[R4-bgp]peer 10.0.1.1 as-number 64512

[R4-bgp]peer 10.0.1.1 ebgp-max-hop 2

[R4-bgp]peer 10.0.1.1 connect-interface LoopBack0

[R4-bgp]quit

对等体关系建立完成后，使用**display bgp peer**检查对等体关系状态。

[R4]display bgp peer

BGP local router ID : 10.0.4.4

Local AS number : 64513

Total number of peers : 1 Peers in established state : 1

Peer V AS MsgRcvd MsgSent OutQ Up/Down State PrefRcv

10.0.1.1 4 64512 4 5 0 00:01:18 Established 0

在R4上使用**debugging ip packet verbose**查看keepalive报文的TTL值。

<R4>terminal monitor

<R4>terminal debugging

<R4>debugging ip packet

<R4>

Oct 31 2016 17:22:44.900.2+00:00 R4 IP/7/debug\_case:

Receiving, interface = Serial1/0/0, version = 4, headlen = 20, tos = 192,

pktlen = 40, pktid = 429, offset = 0, ttl = 2, protocol = 6,

checksum = 40287, s = 10.0.1.1, d = 10.0.4.4

prompt: IP Process By Board Begin!

45 c0 00 28 01 ad 00 00 02 06 9d 5f 0a 00 01 01

0a 00 04 04

Oct 31 2016 17:22:44.900.3+00:00 R4 IP/7/debug\_case:

Receiving, interface = Serial1/0/0, version = 4, headlen = 20, tos = 192,

pktlen = 40, pktid = 429, offset = 0, ttl = 2, protocol = 6,

checksum = 40287, s = 10.0.1.1, d = 10.0.4.4

prompt: Before search fib per flow in IP Forward.

可以看到收到的报文中TTL都为2。

在R3和R5之间也建立EBGP对等体关系。直接使用物理接口地址建立连接。

[R3]bgp 64512

[R3-bgp]peer 10.0.35.5 as-number 64514

[R3-bgp]quit

[R5]router id 10.0.5.5

[R5]bgp 64514

[R5-bgp]peer 10.0.35.3 as-number 64512

[R5-bgp]quit

[R5]display bgp peer

BGP local router ID : 10.0.5.5

Local AS number : 64514

Total number of peers : 1 Peers in established state : 1

Peer V AS MsgRcvd MsgSent OutQ Up/Down State PrefRcv

10.0.35.3 4 64512 2 3 0 00:00:46 Established 0

1. 使用Network命令发布路由信息

在R4上配置Loopback1，地址为10.1.4.4/24。使用**network**命令将该网段发布进BGP。

[R4]interface LoopBack 1

[R4-LoopBack1]ip address 10.1.4.4 24

[R4-LoopBack1]quit

[R4]bgp 64513

[R4-bgp]network 10.1.4.4 24

[R4-bgp]quit

在R1和R3上全局路由表分别查看该路由是否存在。

查看R3上BGP路由表，分析该路由的下一跳信息。

[R1]display ip routing-table

Route Flags: R - relay, D - download to fib

----------------------------------------------------------------------------

Routing Tables: Public

Destinations : 18 Routes : 18

Destination/Mask Proto Pre Cost Flags NextHop Interface

10.0.1.1/32 Direct 0 0 D 127.0.0.1 LoopBack0

10.0.2.2/32 OSPF 10 1562 D 10.0.12.2 Serial1/0/0

10.0.3.3/32 OSPF 10 3124 D 10.0.12.2 Serial1/0/0

10.0.4.4/32 Static 60 0 RD 10.0.14.4 Serial3/0/0

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 Serial1/0/0

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 Serial1/0/0

10.0.14.0/24 Direct 0 0 D 10.0.14.1 Serial3/0/0

10.0.14.1/32 Direct 0 0 D 127.0.0.1 Serial3/0/0

10.0.14.4/32 Direct 0 0 D 10.0.14.4 Serial3/0/0

10.0.14.255/32 Direct 0 0 D 127.0.0.1 Serial3/0/0

10.0.23.0/24 OSPF 10 3124 D 10.0.12.2 Serial1/0/0

10.1.4.0/24 EBGP 255 0 RD 10.0.4.4 Serial3/0/0

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

255.255.255.255/3 Direct 0 0 D 127.0.0.1 InLoopBack0

可以看到在R1上已经学到10.1.4.0/24的EBGP路由。

在R3上查看是否有到达网络10.1.4.0/24的路由。

[R3]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

10.0.1.1/32 OSPF 10 3124 D 10.0.23.2 Serial2/0/0

10.0.2.2/32 OSPF 0 1562 D 10.0.23.2 Serial2/0/0

10.0.3.3/32 Direct 0 0 D 127.0.0.1 LoopBack0

10.0.12.0/24 OSPF 10 3124 D 10.0.23.2 Serial2/0/0

10.0.23.0/24 Direct 0 0 D 10.0.23.3 Serial2/0/0

10.0.23.2/32 Direct 0 0 D 10.0.23.2 Serial2/0/0

10.0.23.3/32 Direct 0 0 D 127.0.0.1 Serial2/0/0

10.0.23.255/32 Direct 0 0 D 127.0.0.1 Serial2/0/0

10.0.35.0/24 Direct 0 0 D 10.0.35.3 Serial3/0/0

10.0.35.3/32 Direct 0 0 D 127.0.0.1 Serial3/0/0

10.0.35.5/32 Direct 0 0 D 10.0.35.5 Serial3/0/0

10.0.35.255/32 Direct 0 0 D 127.0.0.1 Serial3/0/0

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

127.255.255.255/32Direct 0 0 D 127.0.0.1 InLoopBack0

255.255.255.255/3 Direct 0 0 D 127.0.0.1 InLoopBack0

在R3上并没有10.1.4.4的bgp路由。

查看R3的BGP表。

[R3]display bgp routing-table

BGP Local router ID is 10.0.3.3

Status codes: \* - valid, > - best, d - damped,

h - history, i - internal, s - suppressed, S - Stale

Origin : i - IGP, e - EGP, ? - incomplete

Total Number of Routes: 1

Network NextHop MED LocPrf PrefVal Path/Ogn

i 10.1.4.0/24 10.0.4.4 0 100 0 64513i

可以在R3的BGP路由表中看到，但是这条BGP路由没有\*号标识，说明这条路由并没有被优选。因为这条路由的NextHop为10.0.4.4，而R3上并没有到达地址10.0.4.4的路由。根据BGP选路原则，当BGP路由的下一跳不可达时，忽略此路由。

在R1上配置**next-hop-local**，再次在R3上查看该路由表。

[R1]bgp 64512

[R1-bgp]peer 10.0.3.3 next-hop-local

[R1-bgp]peer 10.0.2.2 next-hop-local

[R1-bgp]quit

[R3]display bgp routing-table

BGP Local router ID is 10.0.3.3

Status codes: \* - valid, > - best, d - damped,

h - history, i - internal, s - suppressed, S - Stale

Origin : i - IGP, e - EGP, ? - incomplete

Total Number of Routes: 1

Network NextHop MED LocPrf PrefVal Path/Ogn

\*>i 10.1.4.0/24 10.0.1.1 0 100 0 64513i

可以看到BGP路由10.1.4.0/24的下一跳为10.0.1.1，同时具有\*号和>号，说明这条路由是正确并且最优的。

查看R3的路由表。

[R3]display ip routing-table

Route Flags: R - relay, D - download to fib

----------------------------------------------------------------------------

Routing Tables: Public

Destinations : 17 Routes : 17

Destination/Mask Proto Pre Cost Flags NextHop Interface

10.0.1.1/32 OSPF 10 3124 D 10.0.23.2 Serial2/0/0

10.0.2.2/32 OSPF 10 1562 D 10.0.23.2 Serial2/0/0

10.0.3.3/32 Direct 0 0 D 127.0.0.1 LoopBack0

10.0.12.0/24 OSPF 10 3124 D 10.0.23.2 Serial2/0/0

10.0.23.0/24 Direct 0 0 D 10.0.23.3 Serial2/0/0

10.0.23.2/32 Direct 0 0 D 10.0.23.2 Serial2/0/0

10.0.23.3/32 Direct 0 0 D 127.0.0.1 Serial2/0/0

10.0.23.255/32 Direct 0 0 D 127.0.0.1 Serial2/0/0

10.0.35.0/24 Direct 0 0 D 10.0.35.3 Serial3/0/0

10.0.35.3/32 Direct 0 0 D 127.0.0.1 Serial3/0/0

10.0.35.5/32 Direct 0 0 D 10.0.35.5 Serial3/0/0

10.0.35.255/32 Direct 0 0 D 127.0.0.1 Serial3/0/0

10.1.4.0/24 IBGP 255 0 RD 10.0.1.1 Serial2/0/0

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

127.255.255.255/32Direct 0 0 D 127.0.0.1 InLoopBack0

255.255.255.255/3 Direct 0 0 D 127.0.0.1 InLoopBack0

路由表出现路由10.1.4.0/24。

在R5上创建Loopback1，地址为10.1.5.5/24，发布进BGP, 在R3上配置**next-hop-local。**

[R5]interface LoopBack 1

[R5-LoopBack1]ip address 10.1.5.5 24

[R5-LoopBack1]quit

[R5]bgp 64514

[R5-bgp]network 10.1.5.0 24

[R3]bgp 64512

[R3-bgp]peer 10.0.1.1 next-hop-local

[R3-bgp]peer 10.0.2.2 next-hop-local

在R4上查看是否学习到R5的Loopback 1连接网络的路由。分析**display bgp routing-table**的输出。

[R4]display bgp routing-table

BGP Local router ID is 10.0.4.4

Status codes: \* - valid, > - best, d - damped,

h - history, i - internal, s - suppressed, S - Stale

Origin : i - IGP, e - EGP, ? - incomplete

Total Number of Routes: 2

Network NextHop MED LocPrf PrefVal Path/Ogn

\*> 10.1.4.0/24 0.0.0.0 0 0 i

\*> 10.1.5.0/24 10.0.1.1 0 64512 64514i

在R5上使用带源地址ping测试到R4的Loopback1地址的连通性。

[R5]ping -c 1 -a 10.1.5.5 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=252 time=125 ms

--- 10.1.4.4 ping statistics ---

1 packet(s) transmitted

1 packet(s) received

0.00% packet loss

round-trip min/avg/max = 125/125/125 ms

## **附加实验: 思考并验证**

什么情况下用物理地址直接建立EBGP邻居关系比较恰当？

为何默认发给EBGP邻居报文的TTL值为1？ 运行**peer *group\_name* ebgp-max-hop *[ hop-count ]***的默认值是多少？

## **最终设备配置**

**[R1]display current-configuration**

[V200R007C00SPC600]

#

sysname R1

#

router id 10.0.1.1

#

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 10.0.1.1 255.255.255.255

#

bgp 64512

timer keepalive 30 hold 90

peer 10.0.2.2 as-number 64512

peer 10.0.2.2 connect-interface LoopBack0

peer 10.0.3.3 as-number 64512

peer 10.0.3.3 connect-interface LoopBack0

peer 10.0.4.4 as-number 64513

peer 10.0.4.4 ebgp-max-hop 2

peer 10.0.4.4 connect-interface LoopBack0

#

ipv4-family unicast

undo synchronization

peer 10.0.2.2 enable

peer 10.0.2.2 next-hop-local

peer 10.0.3.3 enable

peer 10.0.3.3 next-hop-local

peer 10.0.4.4 enable

#

ospf 1

area 0.0.0.0

network 10.0.12.0 0.0.0.255

network 10.0.1.1 0.0.0.0

#

ip route-static 10.0.4.4 255.255.255.255 10.0.14.4

return

**[R2]display current-configuration**

[V200R007C00SPC600]

#

sysname R2

#

router id 10.0.2.2

#

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 10.0.2.2 255.255.255.255

#

bgp 64512

peer 10.0.1.1 as-number 64512

peer 10.0.1.1 connect-interface LoopBack0

peer 10.0.3.3 as-number 64512

peer 10.0.3.3 connect-interface LoopBack0

#

ipv4-family unicast

undo synchronization

peer 10.0.1.1 enable

peer 10.0.3.3 enable

#

ospf 1

area 0.0.0.0

network 10.0.12.0 0.0.0.255

network 10.0.23.0 0.0.0.255

network 10.0.2.2 0.0.0.0

return

**[R3]display current-configuration**

[V200R007C00SPC600]

#

sysname R3

#

router id 10.0.3.3

#

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 10.0.3.3 255.255.255.255

#

bgp 64512

peer 10.0.1.1 as-number 64512

peer 10.0.1.1 connect-interface LoopBack0

peer 10.0.2.2 as-number 64512

peer 10.0.2.2 connect-interface LoopBack0

peer 10.0.35.5 as-number 64514

#

ipv4-family unicast

undo synchronization

peer 10.0.1.1 enable

peer 10.0.1.1 next-hop-local

peer 10.0.2.2 enable

peer 10.0.2.2 next-hop-local

peer 10.0.35.5 enable

#

ospf 1

area 0.0.0.0

network 10.0.23.0 0.0.0.255

network 10.0.3.3 0.0.0.0

return

**[R4]display current-configuration**

[V200R007C00SPC600]

#

sysname R4

#

router id 10.0.4.4

#

interface Serial1/0/0

link-protocol ppp

ip address 10.0.14.4 255.255.255.0

#

interface LoopBack0

ip address 10.0.4.4 255.255.255.255

#

interface LoopBack1

ip address 10.1.4.4 255.255.255.0

#

bgp 64513

peer 10.0.1.1 as-number 64512

peer 10.0.1.1 ebgp-max-hop 2

peer 10.0.1.1 connect-interface LoopBack0

#

ipv4-family unicast

undo synchronization

network 10.0.4.0 255.255.255.0

network 10.1.4.0 255.255.255.0

peer 10.0.1.1 enable

#

ip route-static 10.0.1.1 255.255.255.255 10.0.14.1

return

**[R5]display current-configuration**

[V200R007C00SPC600]

#

sysname R5

#

router id 10.0.5.5

#

interface Serial1/0/0

link-protocol ppp

ip address 10.0.35.5 255.255.255.0

#

interface LoopBack0

ip address 10.0.5.5 255.255.255.255

#

interface LoopBack1

ip address 10.1.5.5 255.255.255.0

#

bgp 64514

peer 10.0.35.3 as-number 64512

#

ipv4-family unicast

undo synchronization

network 10.1.5.0 255.255.255.0

peer 10.0.35.3 enable

return

实验 3-2 BGP路由汇总

学习目的

* 掌握使用**network**命令实现的BGP路由汇总的配置方法
* 掌握实现抑制具体路由的BGP路由汇总的配置方法
* 掌握改变汇总路由属性的配置方法
* 掌握在路由汇总时使用AS-SET的配置方法

## **拓扑图**

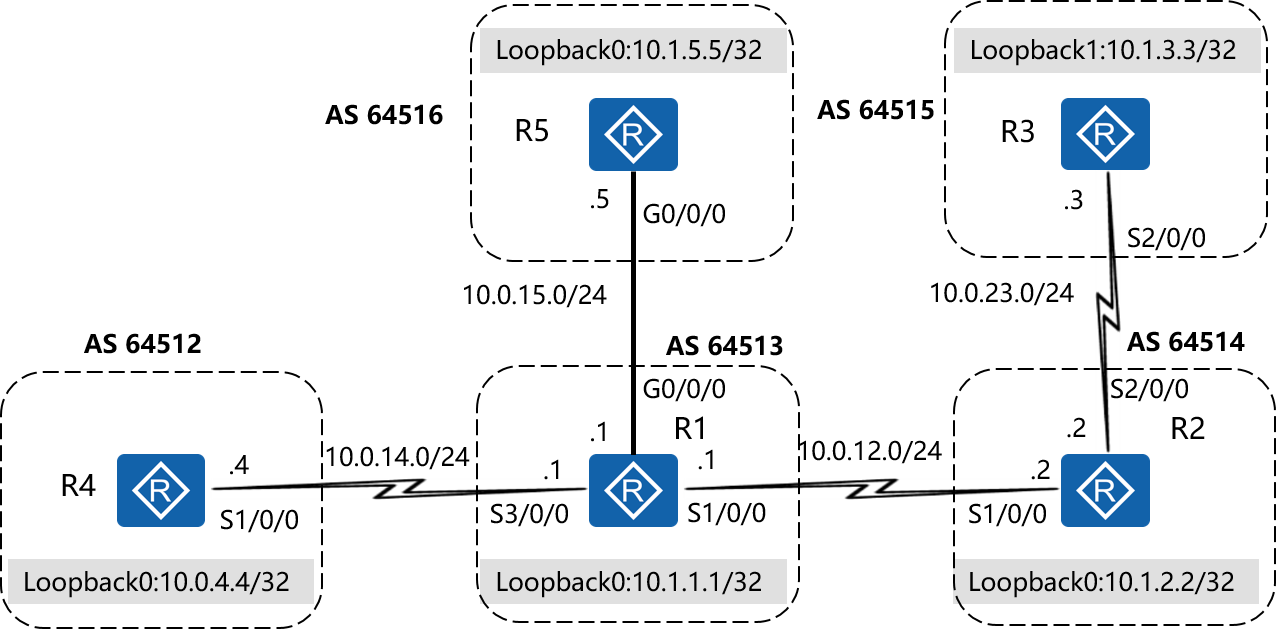


图3-2 BGP路由汇总

## **场景**

你是公司的网络管理员。公司的网络采用了BGP协议作为路由协议。公司的网络由多个自制系统组成，不同的分支机构使用了不同的AS号。随着公司规模的扩大，路由器中已经有越来越多的路由表，进行BGP的路由汇总迫在眉睫。你测试了几种进行路由汇总的方法，最终选择了合适的方式实现了路由汇总。

学习任务

1. 基础配置与IP编址

给所有路由器配置物理接口及Loopback接口的IP地址和掩码。注意各Loopback接口地址均为32位掩码。

[R1]interface Serial 1/0/0

[R1-Serial1/0/0]ip address 10.0.12.1 255.255.255.0

[R1-Serial1/0/0]quit

[R1]interface Serial 3/0/0

[R1-Serial3/0/0]ip address 10.0.14.1 255.255.255.0

[R1-Serial3/0/0]quit

[R1]interface GigabitEthernet 0/0/0

[R1-GigabitEthernet0/0/0]ip add 10.0.15.1 255.255.255.0

[R1-GigabitEthernet0/0/0]quit

[R1]interface LoopBack 0

[R1-LoopBack0]ip address 10.1.1.1 255.255.255.255

[R1-LoopBack0]quit

[R2]interface Serial 1/0/0

[R2-Serial1/0/0]ip address 10.0.12.2 255.255.255.0

[R2-Serial1/0/0]quit

[R2]interface Serial 2/0/0

[R2-Serial2/0/0]ip address 10.0.23.2 255.255.255.0

[R2-Serial2/0/0]quit

[R2]interface loopback 0

[R2-LoopBack0]ip address 10.1.2.2 255.255.255.255

[R2-LoopBack0]quit

[R3]interface Serial 2/0/0

[R3-Serial2/0/0]quit

[R3]ip address 10.0.23.3 255.255.255.0

[R3-Serial2/0/0]quit

[R3]interface loopback 1

[R3-LoopBack1]ip address 10.1.3.3 255.255.255.255

[R3-LoopBack1]quit

[R4]interface Serial 1/0/0

[R4-Serial1/0/0]ip address 10.0.14.4 255.255.255.0

[R4-Serial1/0/0]quit

[R4]interface loopback 0

[R4-LoopBack0]ip address 10.0.4.4 255.255.255.255

[R4-LoopBack0]quit

[R5]interface GigabitEthernet 0/0/0

[R5-GigabitEthernet0/0/0]ip address 10.0.15.5 255.255.255.0

[R5-GigabitEthernet0/0/0]quit

[R5]interface loopback 0

[R5-LoopBack0]ip address 10.1.5.5 255.255.255.255

[R5-LoopBack0]quit

配置完成后，测试直连链路的连通性。

[R1]ping -c 1 10.0.12.2

PING 10.0.12.2: 56 data bytes, press CTRL\_C to break

Reply from 10.0.14.4: bytes=56 Sequence=1 ttl=255 time=41 ms

--- 10.0.12.2 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 10.0.14.4

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=41 ms

--- 10.0.14.4 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 10.0.15.5

PING 10.0.15.5: 56 data bytes, press CTRL\_C to break

Reply from 10.0.15.5: bytes=56 Sequence=1 ttl=255 time=34 ms

--- 10.0.15.5 ping statistics ---

1 packet(s) transmitted

1 packet(s) received

0.00% packet loss

round-trip min/avg/max = 34/34/34 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=34 ms

--- 10.0.23.3 ping statistics ---

1 packet(s) transmitted

1 packet(s) received

0.00% packet loss

round-trip min/avg/max = 34/34/34 ms

1. 配置EBGP及发布路由

各直连路由器之间直接使用物理接口地址建立BGP对等体关系。

[R1]router id 10.1.1.1

[R1]bgp 64513

[R1-bgp]peer 10.0.12.2 as-number 64514

[R1-bgp]peer 10.0.14.4 as-number 64512

[R1-bgp]peer 10.0.15.5 as-number 64516

[R1-bgp]quit

[R2]router id 10.1.2.2

[R2]bgp 64514

[R2-bgp]peer 10.0.12.1 as-number 64513

[R2-bgp]peer 10.0.23.3 as-number 64515

[R2-bgp]quit

[R3]router id 10.1.3.3

[R3]bgp 64515

[R3-bgp]peer 10.0.23.2 as-number 64514

[R3-bgp]quit

[R4]router id 10.0.4.4

[R4]bgp 64512

[R4-bgp]peer 10.0.14.1 as-number 64513

[R4-bgp]quit

[R5]router id 10.1.5.5

[R5]bgp 64516

[R5-bgp]peer 10.0.15.1 as-number 64513

[R5-bgp]quit

配置完成以后检查对等体关系，

[R1]display bgp peer

BGP local router ID : 10.1.1.1

Local AS number : 64513

Total number of peers : 3 Peers in established state : 3

Peer V AS MsgRcvd MsgSent OutQ Up/Down State PrefRcv

10.0.12.2 4 64514 4 6 0 00:02:19 Established 0

10.0.14.4 4 64512 2 4 0 00:00:40 Established 0

10.0.15.5 4 64516 2 4 0 00:00:17 Established 0

[R2]display bgp peer

BGP local router ID : 10.1.2.2

Local AS number : 64514

Total number of peers : 2 Peers in established state : 2

Peer V AS MsgRcvd MsgSent OutQ Up/Down State PrefRcv

10.0.12.1 4 64513 5 6 0 00:03:42 Established 0

10.0.23.3 4 64515 4 6 0 00:02:25 Established 0

[R3]display bgp peer

BGP local router ID : 10.1.3.3

Local AS number : 64515

Total number of peers : 1 Peers in established state : 1

Peer V AS MsgRcvd MsgSent OutQ Up/Down State PrefRcv

10.0.23.2 4 64514 6 7 0 00:04:55 Established 0

[R4]display bgp peer

BGP local router ID : 10.0.4.4

Local AS number : 64512

Total number of peers : 1 Peers in established state : 1

Peer V AS MsgRcvd MsgSent OutQ Up/Down State PrefRcv

10.0.14.1 4 64513 7 8 0 00:05:11 Established 0

[R5]display bgp peer

BGP local router ID : 10.1.5.5

Local AS number : 64516

Total number of peers : 1 Peers in established state : 1

Peer V AS MsgRcvd MsgSent OutQ Up/Down State PrefRcv

10.0.15.1 4 64513 7 8 0 00:05:16 Established 0

BGP邻居状态此时全部都是Established状态。

使用**network**命令将各个路由器的Loopback接口网段发布进BGP。

[R1]bgp 64513

[R1-bgp]network **10.1.1.1 255.255.255.255**

[R1-bgp]quit

[R2]bgp 64514

[R2-bgp]network **10.1.2.2 255.255.255.255**

[R2-bgp]quit

[R3]bgp 64515

[R3-bgp]network **10.1.3.3 255.255.255.255**

[R3-bgp]quit

[R4]bgp 64512

[R4-bgp]network **10.0.4.4 255.255.255.255**

[R4-bgp]quit

[R5]bgp 64516

[R5-bgp]network **10.1.5.5 255.255.255.255**

[R5-bgp]quit

在R4上查看BGP路由表，观察AS-PATH属性的信息。

[R4]**display bgp routing-table**

BGP Local router ID is 10.0.4.4

Status codes: \* - valid, > - best, d - damped,

h - history, i - internal, s - suppressed, S - Stale

Origin : i - IGP, e - EGP, ? - incomplete

Total Number of Routes: 5

Network NextHop MED LocPrf PrefVal Path/Ogn

\*> 10.0.4.4/32 0.0.0.0 0 0 i

\*> 10.1.1.1/32 10.0.14.1 0 0 64513i

\*> 10.1.2.2/32 10.0.14.1 0 64513 64514i

\*> 10.1.3.3/32 10.0.14.1 0 64513 64514 64515i

\*> 10.1.5.5/32 10.0.14.1 0 64513 64516i

1. 使用Network实现对BGP路由的汇总

现在需要在R1上进行路由汇总。

在R1上添加指向Null0接口的静态路由10.1.0.0/16，并使用**network**命令发布该路由。

[R1]ip route-static 10.1.0.0 16 NULL 0

[R1]bgp 64513

[R1-bgp]network 10.1.0.0 255.255.0.0

[R1-bgp]quit

在R4上查看路由表，观察汇总路由是否存在。

<R4>display bgp routing-table

BGP Local router ID is 10.0.4.4

Status codes: \* - valid, > - best, d - damped,

h - history, i - internal, s - suppressed, S - Stale

Origin : i - IGP, e - EGP, ? - incomplete

Total Number of Routes: 6

Network NextHop MED LocPrf PrefVal Path/Ogn

\*> 10.0.4.4/32 0.0.0.0 0 0 i

\*> 10.1.0.0/16 10.0.14.1 0 0 64513i

\*> 10.1.1.1/32 10.0.14.1 0 0 64513i

\*> 10.1.2.2/32 10.0.14.1 0 64513 64514i

\*> 10.1.3.3/32 10.0.14.1 0 64513 64514 64515i

\*> 10.1.5.5/32 10.0.14.1 0 64513 64516i

设置名为**pref\_detail\_control**的前缀列表，对向对等体R4发送的路由进行过滤，不允许汇总路由中包括的详细路由被发送过去。

[R1]ip ip-prefix **pref\_detail\_control** index 10 permit 10.1.0.0 8 less-equal 24

[R1]bgp 64513

[R1-bgp]peer 10.0.14.4 ip-prefix **pref\_detail\_control** export

[R1-bgp]quit

在R4上再次查看BGP路由表。注意观察汇总后路由的As-path属性。

<R4>display bgp routing-table

BGP Local router ID is 10.0.4.4

Status codes: \* - valid, > - best, d - damped,

h - history, i - internal, s - suppressed, S - Stale

Origin : i - IGP, e - EGP, ? - incomplete

Total Number of Routes: 2

Network NextHop MED LocPrf PrefVal Path/Ogn

\*> 10.0.4.4/32 0.0.0.0 0 0 i

\*> 10.1.0.0/16 10.0.14.1 0 0 64513i

1. 使用Aggregate实现对BGP路由的汇总

删去步骤三中使用的前缀列表及**network**命令发布的汇总路由。

使用**Aggregate**命令对路由10.1.0.0/16进行汇总，使用默认方式进行。

[R1]bgp 64513

[R1-bgp]undo network 10.1.0.0 255.255.0.0

[R1-bgp]undo peer 10.0.14.4 ip-prefix **pref\_detail\_control** export

[R1-bgp]quit

[R1]undo ip ip-prefix **pref\_detail\_control**

[R1]undo ip route-static 10.1.0.0 16 NULL 0

[R1]bgp 64513

[R1-bgp]aggregate10.1.0.0 255.255.0.0

[R1-bgp]quit

在R1、R4查看BGP路由表。观察汇总路由的Origin属性。

[R1]display bgp routing-table

BGP Local router ID is 10.1.1.1

Status codes: \* - valid, > - best, d - damped,

h - history, i - internal, s - suppressed, S - Stale

Origin : i - IGP, e - EGP, ? - incomplete

Total Number of Routes: 6

Network NextHop MED LocPrf PrefVal Path/Ogn

\*> 10.0.4.4/32 10.0.14.4 0 0 64512i

\*> 10.1.0.0/16 127.0.0.1 0 i

\*> 10.1.1.1/32 0.0.0.0 0 0 i

\*> 10.1.2.2/32 10.0.12.2 0 0 64514i

\*> 10.1.3.3/32 10.0.12.2 0 64514 64515i

\*> 10.1.5.5/32 10.0.15.5 0 0 64516i

<R4>display bgp routing-table

BGP Local router ID is 10.0.4.4

Status codes: \* - valid, > - best, d - damped,

h - history, i - internal, s - suppressed, S - Stale

Origin : i - IGP, e - EGP, ? - incomplete

Total Number of Routes: 6

Network NextHop MED LocPrf PrefVal Path/Ogn

\*> 10.0.4.4/32 0.0.0.0 0 0 i

\*> 10.1.0.0/16 10.0.14.1 0 64513i

\*> 10.1.1.1/32 10.0.14.1 0 0 64513i

\*> 10.1.2.2/32 10.0.14.1 0 64513 64514i

\*> 10.1.3.3/32 10.0.14.1 0 64513 64514 64515i

\*> 10.1.5.5/32 10.0.14.1 0 64513 64516i

汇总路由的**origin**属性没有改变，仍旧是IGP。

在R1配置路由汇总时，抑制明细路由，仅通告聚合路由。

[R1]bgp 64513

[R1-bgp]aggregate 10.1.0.0 255.255.0.0 detail-suppressed

[R1-bgp]quit

在R4查看BGP路由表。

[R4]display bgp routing-table

BGP Local router ID is 10.0.4.4

Status codes: \* - valid, > - best, d - damped,

h - history, i - internal, s - suppressed, S - Stale

Origin : i - IGP, e - EGP, ? - incomplete

Total Number of Routes: 2

Network NextHop MED LocPrf PrefVal Path/Ogn

\*> 10.0.4.4/32 0.0.0.0 0 0 i

\*> 10.1.0.0/16 10.0.14.1 0 64513i

这时R4上已经看不到明细路由。

观察R1的全局路由表，查看路由10.1.0.0/16的下一跳。

[R1]display ip routing-table

Route Flags: R - relay, D - download to fib

----------------------------------------------------------------------------

Routing Tables: Public

Destinations : 21 Routes : 21

Destination/Mask Proto Pre Cost Flags NextHop Interface

10.0.4.4/32 EBGP 255 0 D 10.0.14.4 Serial3/0/0

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 Serial1/0/0

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 Serial1/0/0

10.0.14.0/24 Direct 0 0 D 10.0.14.1 Serial3/0/0

10.0.14.1/32 Direct 0 0 D 127.0.0.1 Serial3/0/0

10.0.14.4/32 Direct 0 0 D 10.0.14.4 Serial3/0/0

10.0.14.255/32 Direct 0 0 D 127.0.0.1 Serial3/0/0

10.0.15.0/24 Direct 0 0 D 10.0.15.1 GigabitEthernet0/0/0

10.0.15.1/32 Direct 0 0 D 127.0.0.1 GigabitEthernet0/0/0

10.0.15.255/32 Direct 0 0 D 127.0.0.1 GigabitEthernet0/0/0

10.1.0.0/16 IBGP 255 0 D 0.0.0.0 NULL0

10.1.1.1/32 Direct 0 0 D 127.0.0.1 LoopBack0

10.1.2.2/32 EBGP 255 0 D 10.0.12.2 Serial1/0/0

10.1.3.3/32 EBGP 255 0 D 10.0.12.2 Serial1/0/0

10.1.5.5/32 EBGP 255 0 D 10.0.15.5 GigabitEthernet0/0/0

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

127.255.255.255/32Direct 0 0 D 127.0.0.1 InLoopBack0

255.255.255.255/32Direct 0 0 D 127.0.0.1 InLoopBack0

因为这条聚合路由是R1上配置的，所以出接口为Null0，这样定义的汇总路由有利于避免路由环路的产生。

观察R1的BGP路由表，观察明细路由。

[R1]display bgp routing-table

BGP Local router ID is 10.1.1.1

Status codes: \* - valid, > - best, d - damped,

h - history, i - internal, s - suppressed, S - Stale

Origin : i - IGP, e - EGP, ? - incomplete

Total Number of Routes: 6

Network NextHop MED LocPrf PrefVal Path/Ogn

\*> 10.0.4.4/32 10.0.14.4 0 0 64512i

\*> 10.1.0.0/16 127.0.0.1 0 i

s> 10.1.1.1/32 0.0.0.0 0 0 i

s> 10.1.2.2/32 10.0.12.2 0 0 64514i

s> 10.1.3.3/32 10.0.12.2 0 64514 64515i

s> 10.1.5.5/32 10.0.15.5 0 0 64516i

使用了**detail-suppressed**参数，对外仅发送汇总路由，这时在明细路由条目前面多了个标识s，代表在路由汇总时，明细路由被抑制。

1. 改变汇总路由的属性

缺省情况下，BGP不将团体属性发布给任何对等体。

配置R5向R1、R1向R4通告团体属性。

[R5]bgp 64516

**[**R5-bgp]peer 10.0.15.1 advertise-community

**[**R5-bgp]quit

[R1]bgp 64513

[R1-bgp]peer 10.0.14.4 advertise-community

**[**R1-bgp]quit

验证进行路由汇总后团体属性会丢失。

在R5上对R5通告的10.1.5.5/32加上100的团体属性，并向R1通告。

[R5]acl number 2000

[R5-acl-basic-2000]rule 0 permit source 10.1.5.5 0

[R5-acl-basic-2000]quit

[R5]route-policy set\_comm permit node 10

[R5-route-policy]if-match acl 2000

[R5-route-policy]apply community 100

[R5-route-policy]quit

[R5]bgp 64516

[R5-bgp]peer 10.0.15.1 route-policy set\_comm export

[R5-bgp]quit

在R1上查看该路由是否携带该团体属性。

<R1>display bgp routing-table community

BGP Local router ID is 10.1.1.1

Status codes: \* - valid, > - best, d - damped,

h - history, i - internal, s - suppressed, S - Stale

Origin : i - IGP, e - EGP, ? - incomplete

Total Number of Routes: 2

Network NextHop MED LocPrf PrefVal Community

\*> 10.1.5.0/24 10.0.15.5 0 <0:100>

在R4上查看汇总后路由是否携带该属性。

<R4>display bgp routing-table community

Total Number of Routes: 0

R4没有任何携带团体属性的路由。

在R1上配置路由策略**add­\_comm**，将100:2的团体属性加到汇总后的路由上。

[R1]acl number 2000

[R1-acl-basic-2000]rule 0 permit source 10.1.0.0 0.0.255.255

[R1-acl-basic-2000]quit

[R1]route-policy add\_comm permit node 10

[R1-route-policy]if-match acl 2000

[R1-route-policy]apply community 100:2

[R1-route-policy]quit

[R1]bgp 64513

[R1-bgp]aggregate 10.1.0.0 255.255.0.0 attribute-policy add­\_comm

在R4上观察该汇总路由是否携带100:2团体属性。

<R4>display bgp routing-table community

BGP Local router ID is 10.0.4.4

Status codes: \* - valid, > - best, d - damped,

h - history, i - internal, s - suppressed, S - Stale

Origin : i - IGP, e - EGP, ? - incomplete

Total Number of Routes: 2

Network NextHop MED LocPrf PrefVal Community

\*> 10.1.0.0/16 10.0.14.1 0 <100:2>

\*> 10.1.5.5/32 10.0.14.1 0 <0:100>

R4学习到的汇总路由携带该属性。

1. 使用AS-SET配置AS-PATH属性

路由在汇总后，默认会丢弃AS-PATH属性信息，AS-PATH的丢失可能会造成环路。为避免信息丢失带来的风险，汇总路由可以在汇总时添加AS-Set属性。

配置R1在执行路由汇总时添加AS-Set属性。

[R1]bgp 64513

[R1-bgp]aggregate10.1.0.0 255.255.0.0detail-suppressed as-set

[R1-bgp]quit

观察R1、R4中BGP路由表中汇总路由的AS-PATH属性信息。

[R1]display bgp routing-table

BGP Local router ID is 10.1.1.1

Status codes: \* - valid, > - best, d - damped,

h - history, i - internal, s - suppressed, S - Stale

Origin : i - IGP, e - EGP, ? - incomplete

Total Number of Routes: 6

Network NextHop MED LocPrf PrefVal Path/Ogn

\*> 10.0.4.4/32 10.0.14.4 0 0 64512i

\*> 10.1.0.0/16 127.0.0.1 0 {64514 64515 64516}i

s> 10.1.1.1/32 0.0.0.0 0 0 i

s> 10.1.2.2/32 10.0.12.2 0 0 64514i

s> 10.1.3.3/32 10.0.12.2 0 64514 64515i

s> 10.1.5.5/32 10.0.15.5 0 0 64516i

<R4>display bgp routing-table

BGP Local router ID is 10.0. 4.4

Status codes: \* - valid, > - best, d - damped,

h - history, i - internal, s - suppressed, S - Stale

Origin : i - IGP, e - EGP, ? - incomplete

Total Number of Routes: 2

Network NextHop MED LocPrf PrefVal Path/Ogn

\*> 10.0.4.4/32 0.0.0.0 0 0 i

\*> 10.1.0.0/16 10.0.14.1 0 64513 {64514 64515 64516}i

加了AS-Set属性之后的汇总路由的AS-PATH包含了具体路由的AS路径信息。

在R3上停止通告10.1.3.3/32，重置对等体关系。

[R3]bgp 64515

[R3-bgp]undo network10.1.3.3 255.255.255.255

[R3-bgp]return

<R3>reset bgp all

待邻居关系重新建立后，观察R4上学习到的汇总路由的AS-PATH属性信息。

<R4>display bgp routing-table

BGP Local router ID is 10.0.4.4

Status codes: \* - valid, > - best, d - damped,

h - history, i - internal, s - suppressed, S - Stale

Origin : i - IGP, e - EGP, ? - incomplete

Total Number of Routes: 2

Network NextHop MED LocPrf PrefVal Path/Ogn

\*> 10.0.4.4/32 0.0.0.0 0 0 i

\*> 10.1.0.0/16 10.0.14.1 0 64513 {64514 64516}i

这时发现AS-PATH属性中已经没有AS号码64515。

## **附加实验: 思考并验证**

这个例子中，完成步骤六以后，R5是否能访问到R3的Loopback地址？

**Aggregate**和**Summary automatic**有什么区别？

## **最终设备配置**

<R1>**display current-configuration**

[V200R007C00SPC600]

#

sysname R1

#

router id 10.1.1.1

#

acl number 2000

rule 0 permit source 10.1.0.0 0.0.255.255

#

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 GigabitEthernet0/0/0

ip address 10.0.15.1 255.255.255.0

#

interface NULL0

#

interface LoopBack0

ip address 10.1.1.1 255.255.255.255

#

bgp 64513

peer 10.0.12.2 as-number 64514

peer 10.0.14.4 as-number 64512

peer 10.0.15.5 as-number 64516

#

ipv4-family unicast

undo synchronization

aggregate 10.1.0.0 255.255.0.0 as-set detail-suppressed

network 10.1.1.1 255.255.255.255

peer 10.0.12.2 enable

peer 10.0.14.4 enable

peer 10.0.14.4 advertise-community

peer 10.0.15.5 enable

#

route-policy add\_comm permit node 10

if-match acl 2000

apply community 100:2

#

return

<R2>**display current-configuration**

[V200R007C00SPC600]

#

sysname R2

#

router id 10.1.2.2

#

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 10.1.2.2 255.255.255.255

#

bgp 64514

peer 10.0.12.1 as-number 64513

peer 10.0.23.3 as-number 64515

#

ipv4-family unicast

undo synchronization

network 10.1.2.2 255.255.255.255

peer 10.0.12.1 enable

peer 10.0.23.3 enable

#

return

<R3>**display current-configuration**

[V200R007C00SPC600]

#

sysname R3

#

router id 10.1.3.3

#

interface Serial2/0/0

link-protocol ppp

ip address 10.0.23.3 255.255.255.0

#

interface LoopBack1

ip address 10.1.3.3 255.255.255.255

#

bgp 64515

peer 10.0.23.2 as-number 64514

#

ipv4-family unicast

undo synchronization

peer 10.0.23.2 enable

#

return

<R4>**display current-configuration**

[V200R007C00SPC600]

#

sysname R4

#

router id 10.0.4.4

#

interface Serial1/0/0

link-protocol ppp

ip address 10.0.14.4 255.255.255.0

#

interface LoopBack0

ip address 10.0.4.4 255.255.255.255

#

bgp 64512

peer 10.0.14.1 as-number 64513

#

ipv4-family unicast

undo synchronization

network 10.0.4.4 255.255.255.255

peer 10.0.14.1 enable

#

return

<R5>**display current-configuration**

[V200R007C00SPC600]

#

sysname R5

#

router id 10.1.5.5

#

acl number 2000

rule 0 permit source 10.1.5.5 0

#

interface GigabitEthernet0/0/0

ip address 10.0.15.5 255.255.255.0

#

interface LoopBack0

ip address 10.1.5.5 255.255.255.255

#

bgp 64516

peer 10.0.15.1 as-number 64513

#

ipv4-family unicast

undo synchronization

network 10.1.5.5 255.255.255.255

peer 10.0.15.1 enable

peer 10.0.15.1 advertise-community

peer 10.0.15.1 route-policy set\_comm export

#

route-policy set\_comm permit node 10

if-match acl 2000

apply community 100

#

return

实验 3-3 BGP属性与路径选择1

学习目的

* 掌握通过配置AS-Path属性来影响路径选择的方法
* 掌握通过修改Origin属性来影响路径选择的配置方法
* 掌握通过修改Local-Pref属性来影响路径选择的配置方法
* 掌握通过修改MED属性来影响路径选择的配置方法

## **拓扑图**

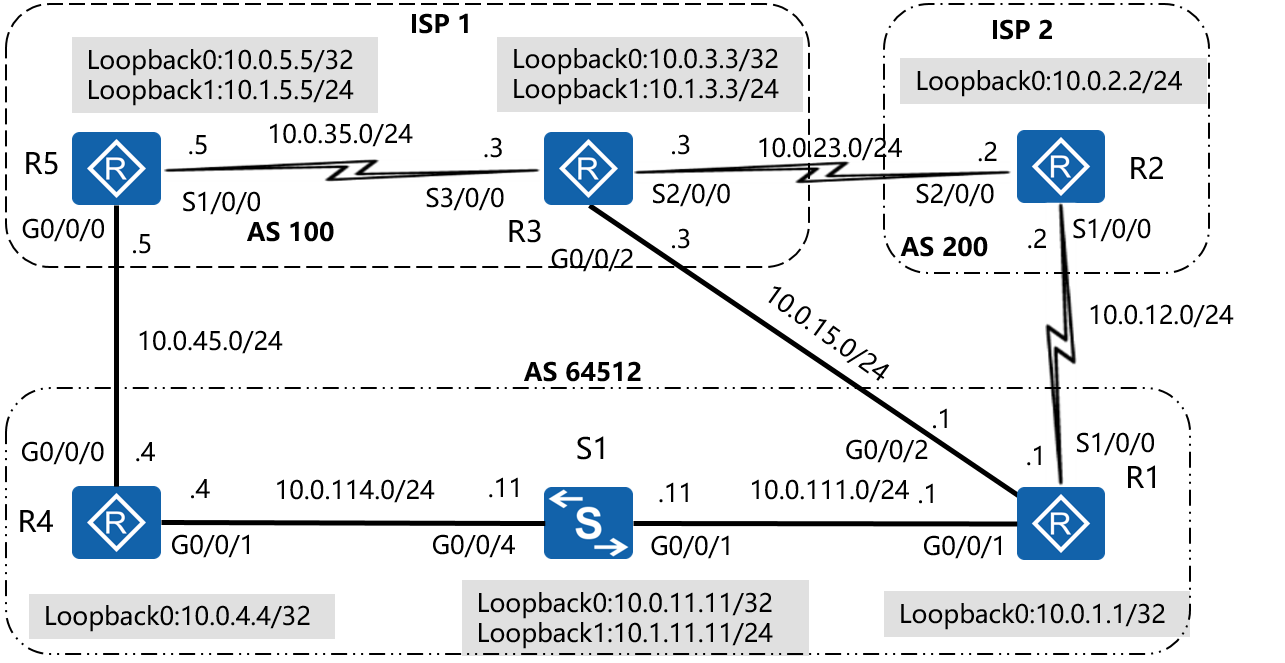


图3-3 BGP属性与路径选择

## **场景**

你是公司的网络管理员。公司的网络采用了BGP协议接入了两个服务运营商。公司自己采用了私有的AS号64512，ISP1的AS号为100，公司共有2条链路接入ISP1。ISP2的AS号为200，公司租用了一条线路接入ISP2。现在Internet上的部分用户反应访问公司网站的速度较慢，你通过改变BGP的各种属性达到了调整路由走向的目的。

学习任务

1. 基础配置与IP编址

给所有路由器配置物理接口及Loopback接口的IP地址和掩码。注意各Loopback 0接口均使用32位掩码。

[R1]interface Serial 1/0/0

[R1-Serial1/0/0]ip address 10.0.12.1 24

[R1-Serial1/0/0]quit

[R1]interface GigabitEthernet 0/0/2

[R1-GigabitEthernet0/0/2]ip address 10.0.15.1 24

[R1-GigabitEthernet0/0/2]quit

[R1]interface GigabitEthernet 0/0/1

[R1-GigabitEthernet0/0/1]ip address 10.0.111.1 24

[R1-GigabitEthernet0/0/1]quit

[R1]interface LoopBack 0

[R1-LoopBack0]ip address 10.0.1.1 32

[R1-LoopBack0]quit

[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 LoopBack 0

[R2-LoopBack0]ip address 10.0.2.2 24

[R2-LoopBack0]quit

[R3]interface GigabitEthernet 0/0/2

[R3-GigabitEthernet0/0/2]ip address 10.0.15.3 24

[R3-GigabitEthernet0/0/2]quit

[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 32

[R3-LoopBack0]quit

[R4]interface GigabitEthernet 0/0/1

[R4-GigabitEthernet0/0/1]ip address 10.0.114.4 24

[R4-GigabitEthernet0/0/1]quit

[R4]interface GigabitEthernet 0/0/0

[R4-GigabitEthernet0/0/0]ip address 10.0.45.4 24

[R4-GigabitEthernet0/0/0]quit

[R4]interface loopback 0

[R4-LoopBack0]ip address 10.0.4.4 32

[R4-LoopBack0]quit

[R5]interface Serial 1/0/0

[R5-Serial1/0/0]ip address 10.0.35.5 24

[R5-Serial1/0/0]quit

[R5]interface GigabitEthernet 0/0/0

[R5-GigabitEthernet0/0/0]ip address 10.0.45.5 24

[R5-GigabitEthernet0/0/0]quit

[R5]interface loopback 0

[R5-LoopBack0]ip address 10.0.5.5 32

[R5-LoopBack0]quit

配置完成后，测试直连链路的连通性。

<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=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

[R1]ping -c 1 10.0.15.3

PING 10.0.15.3: 56 data bytes, press CTRL\_C to break

Reply from 10.0.15.3: bytes=56 Sequence=1 ttl=255 time=59 ms

--- 10.0.15.3 ping statistics ---

1 packet(s) transmitted

1 packet(s) received

0.00% packet loss

round-trip min/avg/max = 59/59/59 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=32 ms

--- 10.0.23.3 ping statistics ---

1 packet(s) transmitted

1 packet(s) received

0.00% packet loss

round-trip min/avg/max = 32/32/32 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=36 ms

--- 10.0.35.5 ping statistics ---

1 packet(s) transmitted

1 packet(s) received

0.00% packet loss

round-trip min/avg/max = 36/36/36 ms

<R4>ping -c 1 10.0.45.5

PING 10.0.45.5: 56 data bytes, press CTRL\_C to break

Reply from 10.0.45.5: bytes=56 Sequence=1 ttl=255 time=11 ms

--- 10.0.45.5 ping statistics ---

1 packet(s) transmitted

1 packet(s) received

0.00% packet loss

round-trip min/avg/max = 11/11/11 ms

1. 配置IGP及BGP

在AS 64512内部使用OSPF作为IGP，所有设备属于区域0。

R1的G0/0/1和Loopback 0连接的网段运行OSPF。

[R1]router id 10.0.1.1

[R1]ospf 1

[R1-ospf-1]area 0

[R1-ospf-1-area-0.0.0.0]network 10.0.111.1 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]quit

在S1上创建Vlan 111，配置Vlanif地址与R1进行互联。

创建Vlan114，配置Vlanif地址与R4进行互联。

互联接口使用Access模式，S1的Vlanif 111、Vlanif 114 和Loopback 0连接的网段运行OSPF。

[S1]router id 10.0.11.11

[S1]vlan batch 111 114

[S1]interface vlan 111

[S1-Vlanif111]ip address 10.0.111.11 24

[S1-Vlanif111]quit

[S1]interface vlan 114

[S1-Vlanif114]ip address 10.0.114.11 24

[S1-Vlanif114]quit

[S1]interface loopback 0

[S1-LoopBack0]ip address 10.0.11.11 32

[S1-LoopBack0]quit

[S1]interface GigabitEthernet 0/0/1

[S1-GigabitEthernet0/0/1]port link-type access

[S1-GigabitEthernet0/0/1]port default vlan 111

[S1-GigabitEthernet0/0/1]quit

[S1]interface GigabitEthernet 0/0/4

[S1-GigabitEthernet0/0/4]port link-type access

[S1-GigabitEthernet0/0/4]port default vlan 114

[S1-GigabitEthernet0/0/4]quit

[S1]ospf 1

[S1-ospf-1]area 0

[S1-ospf-1-area-0.0.0.0]network 10.0.111.11 0.0.0.0

[S1-ospf-1-area-0.0.0.0]network 10.0.114.11 0.0.0.0

[S1-ospf-1-area-0.0.0.0]network 10.0.11.11 0.0.0.0

[S1-ospf-1-area-0.0.0.0]quit

[S1-ospf-1]quit

R4的G0/0/1和Loopback 0连接的网段运行OSPF，

[R4]router id 10.0.4.4

[R4]ospf 1

[R4-ospf-1]area 0

[R4-ospf-1-area-0.0.0.0]network 10.0.114.4 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]quit

[R4-ospf-1]quit

检查是否学习到其他设备的Loopback 0地址所在的网段。

[R1]display ip routing-table

Route Flags: R - relay, D - download to fib

----------------------------------------------------------------------------

Routing Tables: Public

Destinations : 18 Routes : 18

Destination/Mask Proto Pre Cost Flags NextHop Interface

10.0.1.1/32 Direct 0 0 D 127.0.0.1 LoopBack0

10.0.4.4/32 OSPF 10 2 D 10.0.111.11 GigabitEthernet0/0/1

10.0.11.11/32 OSPF 10 1 D 10.0.111.11 GigabitEthernet0/0/1

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 Serial1/0/0

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 Serial1/0/0

10.0.15.0/24 Direct 0 0 D 10.0.15.1 GigabitEthernet0/0/2

10.0.15.1/32 Direct 0 0 D 127.0.0.1 GigabitEthernet0/0/2

10.0.15.255/32 Direct 0 0 D 127.0.0.1 GigabitEthernet0/0/2

10.0.111.0/24 Direct 0 0 D 10.0.111.1 GigabitEthernet0/0/1

10.0.111.1/32 Direct 0 0 D 127.0.0.1 GigabitEthernet0/0/1

10.0.111.255/32 Direct 0 0 D 127.0.0.1 GigabitEthernet0/0/1

10.0.114.0/24 OSPF 10 2 D 10.0.111.11 GigabitEthernet0/0/1

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

127.255.255.255/32Direct 0 0 D 127.0.0.1 InLoopBack0

255.255.255.255/32Direct 0 0 D 127.0.0.1 InLoopBack0

[S1]display ip routing-table

Route Flags: R - relay, D - download to fib

----------------------------------------------------------------------------

Routing Tables: Public

Destinations : 9 Routes : 9

Destination/Mask Proto Pre Cost Flags NextHop Interface

10.0.1.1/32 OSPF 10 1 D 10.0.111.1 Vlanif111

10.0.4.4/32 OSPF 10 1 D 10.0.114.4 Vlanif114

10.0.11.11/32 Direct 0 0 D 127.0.0.1 LoopBack0

10.0.111.0/24 Direct 0 0 D 10.0.111.11 Vlanif111

10.0.111.11/32 Direct 0 0 D 127.0.0.1 Vlanif111

10.0.114.0/24 Direct 0 0 D 10.0.114.11 Vlanif114

10.0.114.11/32 Direct 0 0 D 127.0.0.1 Vlanif114

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

<R4>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

10.0.1.1/32 OSPF 10 2 D 10.0.114.11 GigabitEthernet0/0/1

10.0.4.4/32 Direct 0 0 D 127.0.0.1 LoopBack0

10.0.11.11/32 OSPF 10 1 D 10.0.114.11 GigabitEthernet0/0/1

10.0.45.0/24 Direct 0 0 D 10.0.45.4 GigabitEthernet0/0/0

10.0.45.4/32 Direct 0 0 D 127.0.0.1 GigabitEthernet0/0/0

10.0.45.255/32 Direct 0 0 D 127.0.0.1 GigabitEthernet0/0/0

10.0.111.0/24 OSPF 10 2 D 10.0.114.11 GigabitEthernet0/0/1

10.0.114.0/24 Direct 0 0 D 10.0.114.4 GigabitEthernet0/0/1

10.0.114.4/32 Direct 0 0 D 127.0.0.1 GigabitEthernet0/0/1

10.0.114.255/32 Direct 0 0 D 127.0.0.1 GigabitEthernet0/0/1

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

127.255.255.255/32Direct 0 0 D 127.0.0.1 InLoopBack0

255.255.255.255/32Direct 0 0 D 127.0.0.1 InLoopBack0

在R1、R4、S1上配置BGP，要求使用各自的Loopback 0接口建立对等体连接，配置的时候使用对等体组，组名为**as64512**。

默认情况下，BGP的负载分担是关闭的。在所有的路由器上打开负载分担，设置最大同时使用4条等价路径。

[R1]bgp 64512

[R1-bgp]group as64512 internal

[R1-bgp]peer 10.0.11.11 group as64512

[R1-bgp]peer 10.0.11.11 connect-interface LoopBack 0

[R1-bgp]maximum load-balancing 4

[R1-bgp]quit

[S1]bgp 64512

[S1-bgp]group as64512 internal

[S1-bgp]peer 10.0.4.4 group as64512

[S1-bgp]peer 10.0.4.4 connect-interface LoopBack 0

[S1-bgp]maximum load-balancing 4

[S1-bgp]peer 10.0.1.1 group as64512

[S1-bgp]peer 10.0.1.1 connect-interface LoopBack 0

[S1-bgp]quit

[R4]bgp 64512

[R4-bgp]group as64512 internal

[R4-bgp]peer 10.0.11.11 group as64512

[R4-bgp]peer 10.0.11.11 connect-interface LoopBack 0

[R4-bgp]maximum load-balancing 4

[R4-bgp]quit

在R1、R2、R3、R4、R5上配置EBGP，AS的规划如图所示，EBGP全部使用物理接口地址建立对等体关系。

[R1]bgp 64512

[R1-bgp]peer 10.0.12.2 as-number 200

[R1-bgp]peer 10.0.15.3 as-number 100

[R1-bgp]quit

[R2]router id 10.0.2.2

[R2]bgp 200

[R2-bgp]peer 10.0.12.1 as-number 64512

[R2-bgp]peer 10.0.23.3 as-number 100

[R2-bgp]maximum load-balancing 4

[R2-bgp]quit

[R3]router id 10.0.3.3

[R3]bgp 100

[R3-bgp]peer 10.0.23.2 as-number 200

[R3-bgp]peer 10.0.35.5 as-number 100

[R3-bgp]peer 10.0.15.1 as-number 64512

[R3-bgp]maximum load-balancing 4

[R3-bgp]quit

[R4]bgp 64512

[R4-bgp]peer 10.0.45.5 as-number 100

[R4-bgp]quit

[R5]router id 10.0.5.5

[R5]bgp 100

[R5-bgp]peer 10.0.35.3 as-number 100

[R5-bgp]peer 10.0.45.4 as-number 64512

[R5-bgp]maximum load-balancing 4

[R5-bgp]quit

1. 配置AS-Path属性

在S1上创建Loopback 1，地址为10.1.11.11/24，使用**network**命令发布到BGP中。

[S1]interface loopback 1

[S1-LoopBack1]ip address 10.1.11.11 24

[S1-LoopBack1]quit

[S1]bgp 64512

[S1-bgp]network 10.1.11.11 255.255.255.0

[S1]quit

在R2上观察BGP路由表，可看出这时10.1.11.0/24路由是依据AS-Path属性来选择下一跳的。

[R2]display bgp routing-table

BGP Local router ID is 10.0.2.2

Status codes: \* - valid, > - best, d - damped,

h - history, i - internal, s - suppressed, S - Stale

Origin : i - IGP, e - EGP, ? - incomplete

Total Number of Routes: 2

Network NextHop MED LocPrf PrefVal Path/Ogn

\*> 10.1.11.0/24 10.0.12.1 0 64512i

\* 10.0.23.3 0 100 64512i

由于R1到R4之间的带宽有限，现在希望R2能经由AS100来访问10.1.11.0/24。

这里通过AS-Path来影响选路。

在R1上创建路由策略**as\_path**，针对10.1.11.0/24这条路由增加2个重复的AS号。

[R1]acl number 2001

[R1-acl-basic-2001]rule 5 permit source 10.1.11.0 0.0.0.255

[R1-acl-basic-2001]quit

[R1]route-policy as\_path permit node 10

[R1-route-policy]if-match acl 2001

[R1-route-policy]apply as-path 64512 64512 additive

[R1-route-policy]quit

然后把该策略应用在R1上，让R2从R1上学习到的这条路由的AS-Path有3个值。

[R1]bgp 64512

[R1-bgp]peer 10.0.12.2 route-policy as\_path export

[R1-bgp]quit

在R2上观察BGP路由表。

<R2>display bgp routing-table

BGP Local router ID is 10.0.2.2

Status codes: \* - valid, > - best, d - damped,

h - history, i - internal, s - suppressed, S - Stale

Origin : i - IGP, e - EGP, ? - incomplete

Total Number of Routes: 2

Network NextHop MED LocPrf PrefVal Path/Ogn

\*> 10.1.11.0/24 10.0.23.3 0 100 64512i

\* 10.0.12.1 0 64512 64512 64512i

此时R2经由 AS100访问10.1.11.0/24网段。

1. 配置Origin属性

观察R3的路由表。

<R3>display bgp routing-table

BGP Local router ID is 10.0.3.3

Status codes: \* - valid, > - best, d - damped,

h - history, i - internal, s - suppressed, S - Stale

Origin : i - IGP, e - EGP, ? - incomplete

Total Number of Routes: 2

Network NextHop MED LocPrf PrefVal Path/Ogn

\*> 10.1.11.0/24 10.0.15.1 0 64512i

\* i 10.0.35.5 100 0 64512i

到达10.1.11.0/24的下一跳是R1，分析原因。

我们希望R3通过R5访问AS 64512，查看10.1.11.0/24原来的Origin属性是IGP。

这时，我们将R1对R3通告的该路由修改为incomplete。

[R1]route-policy 22 permit node 10

[R1-route-policy]if-match acl 2001

[R1-route-policy]apply origin incomplete

[R1-route-policy]quit

[R1]bgp 64512

[R1-bgp]peer 10.0.15.3 route-policy 22 export

[R1-bgp]quit

策略生效后观察R3的BGP路由表。

<R3>display bgp routing-table

BGP Local router ID is 10.0.3.3

Status codes: \* - valid, > - best, d - damped,

h - history, i - internal, s - suppressed, S - Stale

Origin : i - IGP, e - EGP, ? - incomplete

Total Number of Routes: 2

Network NextHop MED LocPrf PrefVal Path/Ogn

\*>i 10.1.11.0/24 10.0.35.5 100 0 64512i

\* 10.0.15.1 0 64512?

这时R3到达网络10.1.11.0/24的下一跳是R5。

1. 配置Local-Pref属性

本地优先属性在选路中有很高的优先级。

通过改变本地优先属性可以影响选路。

在R3上创建Loopback 1，地址为10.1.3.3/24，发布进BGP。

[R3]interface loopback 1

[R3-LoopBack1]ip address 10.1.3.3 255.255.255.0

[R3-LoopBack1]quit

[R3]bgp 100

[R3-bgp]network 10.1.3.3 255.255.255.0

[R3-bgp]quit

在R5上创建Loopback 1，地址为10.1.5.5/24，发布进BGP。

[R5]interface loopback 1

[R5-LoopBack1]ip address 10.1.5.5 255.255.255.0

[R5-LoopBack1]quit

[R5]bgp 100

[R5-bgp]network 10.1.5.5 24

[R5-bgp]quit

在S1上观察路由表。

[S1]display bgp routing-table

BGP Local router ID is 10.0.11.11

Status codes: \* - valid, > - best, d - damped,

h - history, i - internal, s - suppressed, S - Stale

Origin : i - IGP, e - EGP, ? - incomplete

Total Number of Routes: 5

Network NextHop MED LocPrf PrefVal Path/Ogn

\*>i 10.1.3.0/24 10.0.1.1 0 100 0 100i

\* i 10.0.4.4 100 0 100i

\*>i 10.1.5.0/24 10.0.1.1 100 0 100i

\* i 10.0.4.4 0 100 0 100i

\*> 10.1.11.0/24 0.0.0.0 0 0 i

现在希望到达网络10.1.5.0/24的流量从R4发送到目标，到达网络10.1.3.0/24的流量从R1发送到目标。

在R4上创建路由策略Pref4，匹配路由10.1.5.0/24，将其本地优先属性修改为110。

R1上创建路由策略Pref1，匹配路由10.1.3.0/24，将其本地优先属性修改为110，然后将策略应用到IBGP的对等体组上。

[R4]acl number 2001

[R4-acl-basic-2001]rule 5 permit source 10.1.5.0 0.0.0.255

[R4-acl-basic-2001]quit

[R4]route-policy Pref4 permit node 10

[R4-route-policy]if-match acl 2001

[R4-route-policy]apply local-preference 110

[R4-route-policy]quit

[R4]route-policy Pref4 permit node 20

[R4-route-policy]quit

[R4]bgp 64512

[R4-bgp]peer as64512 route-policy Pref4 export

[R4-bgp]quit

[R1]acl number 2002

[R1-acl-basic-2002]rule 5 permit source 10.1.3.0 0.0.0.255

[R1-acl-basic-2002]quit

[R1]route-policy Pref1 permit node 10

[R1-route-policy]if-match acl 2002

[R1-route-policy]apply local-preference 110

[R1-route-policy]quit

[R1]route-policy Pref1 permit node 20

[R1-route-policy]quit

[R1]bgp 64512

[R1-bgp]peer as64512 route-policy Pref1 export

[R1-bgp]quit

在S1上查看BGP路由表。

[S1]display bgp routing-table

BGP Local router ID is 10.0.11.11

Status codes: \* - valid, > - best, d - damped,

h - history, i - internal, s - suppressed, S - Stale

Origin : i - IGP, e - EGP, ? – incomplete

Total Number of Routes: 5

Network NextHop MED LocPrf PrefVal Path/Ogn

\*>i 10.1.3.0/24 10.0.1.1 0 110 0 100i

\* i 10.0.4.4 100 0 100i

\*>i 10.1.5.0/24 10.0.4.4 0 110 0 100i

\* i 10.0.1.1 0 100 0 100i

\*> 10.1.11.0/24 0.0.0.0 0 0 i

可以观察到，此时根据Local-Pref属性进行选路，越高越优先。

1. 配置MED属性

删除步骤四中通过修改Origin来影响AS100中对10.1.11.0/24选路的路由策略，本实验中通过修改MED值来影响选路。

[R1]bgp 64512

[R1-bgp]undo peer 10.0.15.3 route-policy 22 export

[R1-bgp]quit

[R1]undo route-policy 22

在R1上创建路由策略**med**，针对10.1.11.0/24，将MED值修改为100，将该策略应用到对等体R3上。

[R1]route-policy med permit node 10

[R1-route-policy]if-match acl 2001

[R1-route-policy]apply cost 100

[R1-route-policy]quit

[R1]bgp 64512

[R1-bgp]peer 10.0.15.3 route-policy med export

[R1-bgp]quit

在R3上查看BGP路由表。

<R3>display bgp routing-table

BGP Local router ID is 10.0.15.3

Status codes: \* - valid, > - best, d - damped,

h - history, i - internal, s - suppressed, S - Stale

Origin : i - IGP, e - EGP, ? - incomplete

Total Number of Routes: 4

Network NextHop MED LocPrf PrefVal Path/Ogn

\*> 10.1.3.0/24 0.0.0.0 0 0 i

\*>i 10.1.5.0/24 10.0.35.5 0 100 0 i

\*>i 10.1.11.0/24 10.0.35.5 100 0 64512i

\* 10.0.15.1 100 0 64512i

[R3]display bgp routing-table 10.1.11.0

BGP local router ID : 10.0.3.3

Local AS number : 100

Paths: 2 available, 1 best, 1 select

BGP routing table entry information of 10.1.11.0/24:

From: 10.0.35.5 (10.0.5.5)

Route Duration: 00h00m33s

Relay IP Nexthop: 0.0.0.0

Relay IP Out-Interface: Serial3/0/0

Original nexthop: 10.0.35.5

Qos information : 0x0

AS-path 64512, origin igp, localpref 100, pref-val 0, valid, internal, best, select, active, pre 255

Advertised to such 2 peers:

10.0.23.2

10.0.15.1

BGP routing table entry information of 10.1.11.0/24:

From: 10.0.15.1 (10.0.1.1)

Route Duration: 18h52m36s

Direct Out-interface: GigabitEthernet0/0/2

Original nexthop: 10.0.15.1

Qos information : 0x0

AS-path 64512, origin igp, MED 100, pref-val 0, valid, external, pre 255, not preferred for MED

Not advertised to any peer yet

MED值越小越优先。

最后观察现象，可以和步骤四中达到同样的选路效果。

## **附加实验: 思考并验证**

思考在完成了步骤六以后，关闭R1的S1/0/0接口，那么在R2上学习到的关于10.1.11.0/24的MED值是多少？

思考可否使用路由策略将AS-Path属性里的某个AS删除？

## **最终设备配置**

<R1>**display current-configuration**

[V200R007C00SPC600]

#

sysname R1

#

router id 10.0.2.2

#

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 GigabitEthernet0/0/1

ip address 10.0.111.1 255.255.255.0

#

interface GigabitEthernet0/0/2

ip address 10.0.15.1 255.255.255.0

#

interface LoopBack0

ip address 10.0.1.1 255.255.255.255

#

bgp 64512

peer 10.0.12.2 as-number 200

peer 10.0.15.3 as-number 100

group as64512 internal

peer 10.0.11.11 as-number 64512

peer 10.0.11.11 group as64512

peer 10.0.11.11 connect-interface LoopBack0

#

ipv4-family unicast

undo synchronization

maximum load-balancing 4

peer 10.0.12.2 enable

peer 10.0.12.2 route-policy as\_path export

peer 10.0.15.3 enable

peer 10.0.15.3 route-policy med export

peer as64512 enable

peer as64512 route-policy Pref1 export

peer 10.0.11.11 enable

peer 10.0.11.11 group as64512

#

ospf 1

area 0.0.0.0

network 10.0.1.1 0.0.0.0

network 10.0.111.1 0.0.0.0

#

route-policy as\_path permit node 10

if-match acl 2001

apply as-path 64512 64512 additive

#

route-policy Pref1 permit node 10

if-match acl 2002

apply local-preference 110

#

route-policy Pref1 permit node 20

#

route-policy med permit node 10

if-match acl 2001

apply cost 100

#

return

<R2>**display current-configuration**

[V200R007C00SPC600]

#

sysname R2

#

router id 10.0.2.2

#

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

#

bgp 200

peer 10.0.12.1 as-number 64512

peer 10.0.23.3 as-number 100

#

ipv4-family unicast

undo synchronization

maximum load-balancing 4

peer 10.0.12.1 enable

peer 10.0.23.3 enable

#

return

<R3>**display current-configuration**

[V200R007C00SPC600]

#

sysname R3

#

router id 10.0.3.3

#

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 GigabitEthernet0/0/2

ip address 10.0.15.3 255.255.255.0

#

interface LoopBack0

ip address 10.0.3.3 255.255.255.255

#

interface LoopBack1

ip address 10.1.3.3 255.255.255.0

#

bgp 100

peer 10.0.15.1 as-number 64512

peer 10.0.23.2 as-number 200

peer 10.0.35.5 as-number 100

#

ipv4-family unicast

undo synchronization

network 10.1.3.0 255.255.255.0

maximum load-balancing 4

peer 10.0.15.1 enable

peer 10.0.23.2 enable

peer 10.0.35.5 enable

#

return

<R4>**display current-configuration**

[V200R007C00SPC600]

#

sysname R4

#

router id 10.0.4.4

#

interface Serial1/0/0

link-protocol ppp

ip address 10.0.14.4 255.255.255.0

#

interface GigabitEthernet0/0/0

ip address 10.0.45.4 255.255.255.0

#

interface GigabitEthernet0/0/1

ip address 10.0.114.4 255.255.255.0

#

interface LoopBack0

ip address 10.0.4.4 255.255.255.255

#

bgp 64512

peer 10.0.45.5 as-number 100

group as64512 internal

peer 10.0.11.11 as-number 64512

peer 10.0.11.11 group as64512

peer 10.0.11.11 connect-interface LoopBack0

#

ipv4-family unicast

undo synchronization

maximum load-balancing 4

peer 10.0.45.5 enable

peer as64512 enable

peer as64512 route-policy Pref4 export

peer 10.0.11.11 enable

peer 10.0.11.11 group as64512

#

ospf 1

area 0.0.0.0

network 10.0.114.4 0.0.0.0

network 10.0.4.4 0.0.0.0

#

route-policy Pref4 permit node 10

if-match acl 2001

apply local-preference 110

#

route-policy Pref4 permit node 20

#

return

<R5>**display current-configuration**

[V200R007C00SPC600]

#

sysname R5

#

router id 10.0.5.5

#

interface Serial1/0/0

link-protocol ppp

ip address 10.0.35.5 255.255.255.0

#

interface GigabitEthernet0/0/0

ip address 10.0.45.5 255.255.255.0

#

interface LoopBack0

ip address 10.0.5.5 255.255.255.255

#

interface LoopBack1

ip address 10.1.5.5 255.255.255.0

#

bgp 100

peer 10.0.35.3 as-number 100

peer 10.0.45.4 as-number 64512

#

ipv4-family unicast

undo synchronization

network 10.1.5.0 255.255.255.0

maximum load-balancing 4

peer 10.0.35.3 enable

peer 10.0.45.4 enable

#

return

实验 3-4 BGP属性与路径选择2(选做)

学习目的

* 掌握通过修改团体属性来影响路径选择的配置方法
* 掌握使用Route-policy来过滤BGP路由信息的配置方法

## **拓扑图**

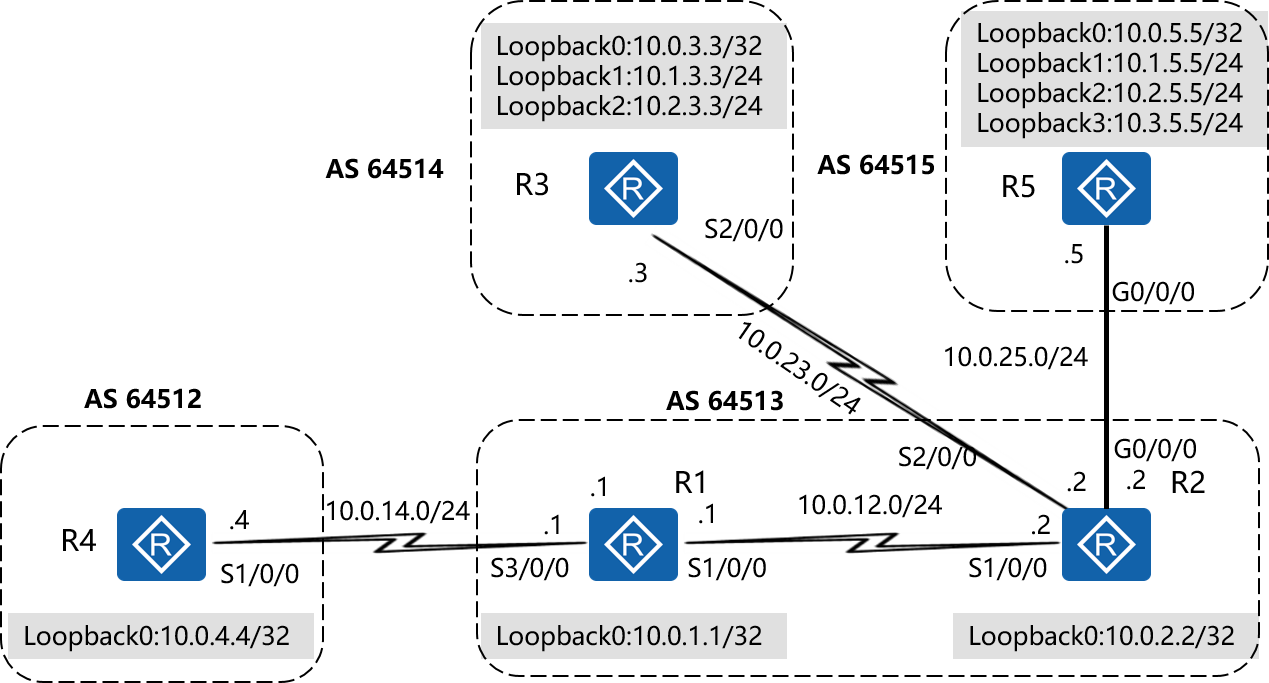


图3-4 BGP属性与路径选择2

## **场景**

你是公司的网络管理员。公司的网络采用了BGP进行互联，BGP的AS号规划如拓扑图中所示。为了公司网络的安全，并非所有分支机构之间的所有部门都能互访。为了控制路由信息的传递，现在你需要使用BGP的团体属性对BGP的路由进行过滤。

学习任务

1. 基础配置与IP编址

给所有路由器配置物理接口及Loopback 0接口的IP地址和掩码。注意各Loopback 0接口地址均使用32位掩码。

<R1>system-view

Enter system view, return user view with Ctrl+Z.

[R1]interface Serial 1/0/0

[R1-Serial1/0/0]ip address 10.0.12.1 255.255.255.0

[R1-Serial1/0/0]quit

[R1]interface Serial 3/0/0

[R1-Serial3/0/0]ip address 10.0.14.1 255.255.255.0

[R1-Serial3/0/0]quit

[R1]interface loopback 0

[R1-LoopBack0]ip address 10.0.1.1 255.255.255.255

[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 10.0.12.2 255.255.255.0

[R2-Serial1/0/0]quit

[R2]interface Serial 2/0/0

[R2-Serial2/0/0]ip address 10.0.23.2 255.255.255.0

[R2-Serial2/0/0]quit

[R2]interface GigabitEthernet 0/0/0

[R2-GigabitEthernet0/0/0]ip address 10.0.25.2 255.255.255.0

[R2-GigabitEthernet0/0/0]quit

[R2]interface loopback 0

[R2-LoopBack0]ip address 10.0.2.2 255.255.255.255

[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 10.0.23.3 255.255.255.0

[R3-Serial2/0/0]

[R3]interface loopback 0

[R3-LoopBack0]ip address 10.0.3.3 255.255.255.255

[R3-LoopBack0]quit

<R4>system-view

Enter system view, return user view with Ctrl+Z.

[R4]interface Serial 1/0/0

[R4-Serial1/0/0]ip address 10.0.14.4 255.255.255.0

[R4-Serial1/0/0]quit

[R4]interface loopback 0

[R4-LoopBack0]ip address 10.0.4.4 255.255.255.255

[R4-LoopBack0]quit

<R5>system-view

Enter system view, return user view with Ctrl+Z.

[R5]interface GigabitEthernet 0/0/0

[R5-GigabitEthernet0/0/0]ip address 10.0.25.5 255.255.255.0

[R5-GigabitEthernet0/0/0]quit

[R5]interface loopback 0

[R5-LoopBack0]ip address 10.0.5.5 255.255.255.255

[R5-LoopBack0]quit

配置完成后，测试直连链路的连通性。

<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=40 ms

--- 10.0.12.2 ping statistics ---

1 packet(s) transmitted

1 packet(s) received

0.00% packet loss

round-trip min/avg/max = 40/40/40 ms

<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=61 ms

--- 10.0.14.4 ping statistics ---

1 packet(s) transmitted

1 packet(s) received

0.00% packet loss

round-trip min/avg/max = 61/61/61 ms

<R2>ping -c 1 10.0.25.5

PING 10.0.25.5: 56 data bytes, press CTRL\_C to break

Reply from 10.0.25.5: bytes=56 Sequence=1 ttl=255 time=14 ms

--- 10.0.25.5 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 10.0.23.2: 56 data bytes, press CTRL\_C to break

Reply from 10.0.23.3: bytes=56 Sequence=1 ttl=255 time=2 ms

--- 10.0.23.3 ping statistics ---

1 packet(s) transmitted

1 packet(s) received

0.00% packet loss

round-trip min/avg/max = 2/2/2 ms

1. 配置BGP

R1与R2之间为IBGP邻居关系，其他路由器之间均为EBGP邻居关系，

[R1]router id 10.0.1.1

[R1]bgp 64513

[R1-bgp]peer 10.0.12.2 as-number 64513

[R1-bgp]peer 10.0.14.4 as-number 64512

[R1-bgp]quit

[R2]router id 10.0.2.2

[R2]bgp 64513

[R2-bgp]peer 10.0.12.1 as-number 64513

[R2-bgp]peer 10.0.23.3 as-number 64514

[R2-bgp]peer 10.0.25.5 as-number 64515

[R2-bgp]quit

[R3]router id 10.0.3.3

[R3]bgp 64514

[R3-bgp]peer 10.0.23.2 as-number 64513

[R3-bgp]quit

[R4]router id 10.0.4.4

[R4]bgp 64512

[R4-bgp]peer 10.0.14.1 as-number 64513

[R4-bgp]quit

[R5]router id 10.0.5.5

[R5]bgp 64515

[R5-bgp]peer 10.0.25.2 as-number 64513

[R5-bgp]quit

在配置完BGP之后检查路由器之间的邻居关系建立情况，

[R1]display bgp peer

BGP local router ID : 10.0.1.1

Local AS number : 64513

Total number of peers : 2 Peers in established state : 2

Peer V AS MsgRcvd MsgSent OutQ Up/Down State PrefRcv

10.0.12.2 4 64513 5 6 0 00:03:28 Established 0

10.0.14.4 4 64512 2 3 0 00:00:39 Established 0

[R2]display bgp peer

BGP local router ID : 10.0.2.2

Local AS number : 64513

Total number of peers : 3 Peers in established state : 3

Peer V AS MsgRcvd MsgSent OutQ Up/Down State PrefRcv

10.0.12.1 4 64513 6 5 0 00:04:00 Established 0

10.0.23.3 4 64514 4 6 0 00:02:44 Established 0

10.0.25.5 4 64515 2 3 0 00:00:41 Established 0

[R3]display bgp peer

BGP local router ID : 10.0.3.3

Local AS number : 64514

Total number of peers : 1 Peers in established state : 1

Peer V AS MsgRcvd MsgSent OutQ Up/Down State PrefRcv

10.0.23.2 4 64513 4 4 0 00:02:59 Established 0

[R4]display bgp peer

BGP local router ID : 10.0.4.4

Local AS number : 64512

Total number of peers : 1 Peers in established state : 1

Peer V AS MsgRcvd MsgSent OutQ Up/Down State PrefRcv

10.0.14.1 4 64513 3 3 0 00:01:40 Established 0

[R5]display bgp peer

BGP local router ID : 10.0.5.5

Local AS number : 64515

Total number of peers : 1 Peers in established state : 1

Peer V AS MsgRcvd MsgSent OutQ Up/Down State PrefRcv

10.0.25.2 4 64513 3 3 0 00:01:23 Established 0

此时BGP邻居状态全部都是Established状态。

1. 配置普通的团体属性

在R5上创建Loopback1、Loopback2和Loopback3，地址分别为10.1.5.5/24、10.2.5.5/24、10.3.5.5/24，并通过**network**命令发布到BGP中。

[R5]interface loopback 1

[R5-LoopBack1]ip address 10.1.5.5 255.255.255.0

[R5-LoopBack1]quit

[R5]interface loopback 2

[R5-LoopBack2]ip address 10.2.5.5 255.255.255.0

[R5-LoopBack2]quit

[R5]interface loopback 3

[R5-LoopBack3]ip address 10.3.5.5 255.255.255.0

[R5-LoopBack3]quit

[R5]bgp 64515

[R5-bgp]network 10.1.5.5 255.255.255.0

[R5-bgp]network 10.2.5.5 255.255.255.0

[R5-bgp]network 10.3.5.5 255.255.255.0

[R5-bgp]quit

[R2]bgp 64513

[R2-bgp]peer 10.0.12.1 next-hop-local

[R2-bgp]quit

在R2和R4上检查该路由信息是否被正确传递。

[R2]**d**isplay bgp routing-table

BGP Local router ID is 10.0.2.2

Status codes: \* - valid, > - best, d - damped,

h - history, i - internal, s - suppressed, S - Stale

Origin : i - IGP, e - EGP, ? - incomplete

Total Number of Routes: 3

Network NextHop MED LocPrf PrefVal Path/Ogn

\*> 10.1.5.0/24 10.0.25.5 0 0 64515i

\*> 10.2.5.0/24 10.0.25.5 0 0 64515i

\*> 10.3.5.0/24 10.0.25.5 0 0 64515i

[R4]display bgp routing-table

BGP Local router ID is 10.0.4.4

Status codes: \* - valid, > - best, d - damped,

h - history, i - internal, s - suppressed, S - Stale

Origin : i - IGP, e - EGP, ? - incomplete

Total Number of Routes: 3

Network NextHop MED LocPrf PrefVal Path/Ogn

\*> 10.1.5.0/24 10.0.14.1 0 64513 64515i

\*> 10.2.5.0/24 10.0.14.1 0 64513 64515i

\*> 10.3.5.0/24 10.0.14.1 0 64513 64515i

在R5上创建路由策略**comm\_r5**，对10.1.5.0/24这条路由添加团体属性为100。

[R5]acl number 2000

[R5-acl-basic-2000]rule 0 permit source 10.1.5.0 0.0.0.255

[R5-acl-basic-2000]quit

[R5]route-policy comm\_r5 permit node 10

[R5-route-policy]if-match acl 2000

[R5-route-policy]apply community 100

[R5-route-policy]quit

[R5]bgp 64515

[R5-bgp]peer 10.0.25.2 route-policy comm\_r5 export

[R5-bgp]quit

为了后面实验的需要，需要允许路由器之间通告团体属性，配置所有BGP邻居之间通告Community属性。

[R1]bgp 64513

[R1-bgp]peer 10.0.14.4 advertise-community

[R1-bgp]peer 10.0.12.2 advertise-community

[R1-bgp]quit

[R2]bgp 64513

[R2-bgp]peer 10.0.12.1 advertise-community

[R2-bgp]peer 10.0.23.3 advertise-community

[R2-bgp]peer 10.0.25.5 advertise-community

[R2-bgp]quit

[R3]bgp 64514

[R3-bgp]peer 10.0.23.2 advertise-community

[R3-bgp]quit

[R4]bgp 64512

[R4-bgp]peer 10.0.14.1 advertise-community

[R4-bgp]quit

[R5]bgp 64515

[R5-bgp]peer 10.0.25.2 advertise-community

[R5-bgp]quit

在R2和R4上查看该属性是否被正常传递。

<R2>display bgp routing-table community

BGP Local router ID is 10.0.2.2

Status codes: \* - valid, > - best, d - damped,

h - history, i - internal, s - suppressed, S - Stale

Origin : i - IGP, e - EGP, ? - incomplete

Total Number of Routes: 5

Network NextHop MED LocPrf PrefVal Community

\*> 10.1.5.0/24 10.0.25.5 0 0 <0:100>

<R4>display bgp routing-table community

BGP Local router ID is 10.0.4.4

Status codes: \* - valid, > - best, d - damped,

h - history, i - internal, s - suppressed, S - Stale

Origin : i - IGP, e - EGP, ? - incomplete

Total Number of Routes: 5

Network NextHop MED LocPrf PrefVal Community

\*> 10.1.5.0/24 10.0.25.5 0 0 <0:100>

1. 配置特殊的团体属性值

在R5上使用路由策略为路由10.2.5.0/24添加特殊的团体属性no-export，使用路由策略为10.3.5.0/24添加特殊的团体属性no-advertise。

这时只需要在R5已创建的路由策略**comm\_r5**的基础上添加入两个新节点语句即可。

[R5]acl 2001

[R5-acl-basic-2001]rule 0 permit source 10.2.5.0 0.0.0.255

[R5-acl-basic-2001]quit

[R5]route-policy comm\_r5 permit node 20

[R5-route-policy]if-match acl 2001

[R5-route-policy]apply community no-export

[R5-route-policy]quit

[R5]acl number 2002

[R5-acl-basic-2002]rule 0 permit source 10.3.5.0 0.0.0.255

[R5-acl-basic-2002]quit

[R5]route-policy comm\_r5 permit node 30

[R5-route-policy]if-match acl 2002

[R5-route-policy]apply community no-advertise

[R5-route-policy]quit

在R2上使用查看学习到的路由的团体属性信息。

<R2>dis bgp routing-table community

BGP Local router ID is 10.0.2.2

Status codes: \* - valid, > - best, d - damped,

h - history, i - internal, s - suppressed, S - Stale

Origin : i - IGP, e - EGP, ? - incomplete

Total Number of Routes: 4

Network NextHop MED LocPrf PrefVal Community

\*> 10.1.5.0/24 10.0.25.5 0 0 <0:100>

\*> 10.2.5.0/24 10.0.25.5 0 0 no-export

\*> 10.3.5.0/24 10.0.25.5 0 0 no-advertise

在R2、R1、R4上分别观察BGP路由表观察这几条路由的传递情况。

<R2>display bgp routing-table

BGP Local router ID is 10.0.2.2

Status codes: \* - valid, > - best, d - damped,

h - history, i - internal, s - suppressed, S - Stale

Origin : i - IGP, e - EGP, ? - incomplete

Total Number of Routes: 3

Network NextHop MED LocPrf PrefVal Path/Ogn

\*> 10.1.5.0/24 10.0.25.5 0 0 64515i

\*> 10.2.5.0/24 10.0.25.5 0 0 64515i

\*> 10.3.5.0/24 10.0.25.5 0 0 64515i

<R1>display bgp routing-table

BGP Local router ID is 10.0.1.1

Status codes: \* - valid, > - best, d - damped,

h - history, i - internal, s - suppressed, S - Stale

Origin : i - IGP, e - EGP, ? - incomplete

Total Number of Routes: 2

Network NextHop MED LocPrf PrefVal Path/Ogn

\*>i 10.1.5.0/24 10.0.12.2 0 100 0 64515i

\*>i 10.2.5.0/24 10.0.12.2 0 100 0 64515i

[R4]display bgp routing-table

BGP Local router ID is 10.0.4.4

Status codes: \* - valid, > - best, d - damped,

h - history, i - internal, s - suppressed, S - Stale

Origin : i - IGP, e - EGP, ? - incomplete

Total Number of Routes: 1

Network NextHop MED LocPrf PrefVal Path/Ogn

\*> 10.1.5.0/24 10.0.14.1 0 64513 64515i

对于使用了特殊团体属性no-export后的BGP路由10.2.5.0/24，R2不向其AS外发送，但会发布给其AS内的R1。而对于使用no-advertise属性的BGP路由10.3.5.0/24，R2则不向任何对等体发送。

1. 配置团体属性在地址汇总中的应用

在R3上创建Loopback 1和Loopback2，地址分别配置为10.1.3.3/24和10.2.3.3/24，并通过**network**命令发布到BGP中。

[R3]interface LoopBack 1

[R3-LoopBack1]ip address 10.1.3.3 255.255.255.0

[R3-LoopBack1]quit

[R3]interface loopback 2

[R3-LoopBack2]ip address 10.2.3.3 255.255.255.0

[R3-LoopBack2]quit

[R3]bgp 64514

[R3-bgp]network 10.1.3.3 255.255.255.0

[R3-bgp]network 10.2.3.3 255.255.255.0

[R3-bgp]quit

现在有一个需求，我们需要将R5发布的10.1.5.0/24和R3发布的10.2.3.0/24汇总成一个A类网段10.0.0.0/8。通告时抑制明细路由，并且该汇总路由最后通告给R4时携带的团体属性为200。对路由10.1.3.0/24保留明细通告给R4。

为了实现这个需求，我们在R3上创建一个名为**comm­­\_r3**的路由策略，对R3发布的路由10.2.3.0/24加上100的团体属性。

[R3]acl number 2001

[R3-acl-basic-2001]rule 0 permit source 10.2.3.0 0.0.0.255

[R3-acl-basic-2001]quit

[R3]route-policy comm­­\_r3 permit node 10

[R3-route-policy]if-match acl 2001

[R3-route-policy]apply community 100

[R3-route-policy]quit

[R3]route-policy comm­­\_r3 permit node 20

[R3-route-policy]quit

[R3]bgp 64514

[R3-bgp]peer 10.0.23.2 route-policy comm­­\_r3 export

[R3-bgp]quit

在R1上观察学习到的10.1.5.0/24和10.2.3.0/24是否都带上了100的团体属性。

<R1>display bgp routing-table community

BGP Local router ID is 10.0.1.1

Status codes: \* - valid, > - best, d - damped,

h - history, i - internal, s - suppressed, S - Stale

Origin : i - IGP, e - EGP, ? - incomplete

Total Number of Routes: 3

Network NextHop MED LocPrf PrefVal Community

\*>i 10.1.5.0/24 10.0.12.2 0 100 0 <0:100>

\*>i 10.2.3.0/24 10.0.12.2 0 100 0 <0:100>

\*>i 10.2.5.0/24 10.0.12.2 0 100 0 no-export

创建一个团体属性过滤列表，过滤出团体属性为100的路由。

[R1]ip community-filter 1 permit 100

创建一个名为**match­\_comm**的路由策略，匹配团体属性为100的路由。

[R1]route-policy match\_comm permit node 10

[R1-route-policy]if-match community-filter 1

[R1-route-policy]quit

创建一个名为**add\_comm**的路由策略，为汇总后路由添加团体属性为200:1。

[R1]route-policy add\_comm permit node 10

[R1-route-policy]apply community 200:1 additive

[R1-route-policy]quit

在R1上进行地址汇总，定义对匹配策略**match­\_comm**的路由进行汇总，并使用策略**add\_comm**添加团体属性。

[R1]bgp 64513

[R1-bgp]aggregate 10.0.0.0 255.0.0.0 detail-suppressed origin-policy match\_comm attribute-policy add\_comm

[R1-bgp]quit

在R4上查看BGP路由表。

<R4>display bgp routing-table

BGP Local router ID is 10.0.4.4

Status codes: \* - valid, > - best, d - damped,

h - history, i - internal, s - suppressed, S - Stale

Origin : i - IGP, e - EGP, ? - incomplete

Total Number of Routes: 2

Network NextHop MED LocPrf PrefVal Path/Ogn

\*> 10.0.0.0 10.0.14.1 0 64513i

\*> 10.1.3.0/24 10.0.14.1 0 64513 64514i

在R4上观察汇总路由的团体属性。

<R4>display bgp routing-table community

BGP Local router ID is 10.0.4.4

Status codes: \* - valid, > - best, d - damped,

h - history, i - internal, s - suppressed, S - Stale

Origin : i - IGP, e - EGP, ? - incomplete

Total Number of Routes: 1

Network NextHop MED LocPrf PrefVal Community

\*> 10.0.0.0 10.0.14.1 0 <200:1>

## **附加实验: 思考并验证**

在步骤四中，如果将10.2.5.0/24这条路由的属性也改成no advertise，思考此时在R2、R1、R4上再分别查看BGP路由表，这几条路由的传递情况。

思考如何在R4上实现同时保留10.1.3.0/24和10.2.3.0/24这两条路由的明细，仅抑制路由10.1.5.0/24的明细。

## **最终设备配置**

<R1>**display current-configuration**

[V200R007C00SPC600]

#

sysname R1

#

router id 10.0.1.1

#

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 10.0.1.1 255.255.255.255

#

bgp 64513

peer 10.0.12.2 as-number 64513

peer 10.0.14.4 as-number 64512

#

ipv4-family unicast

undo synchronization

aggregate 10.0.0.0 255.0.0.0 detail-suppressed origin-policy match\_comm attribute-policy add\_comm

peer 10.0.12.2 enable

peer 10.0.12.2 advertise-community

peer 10.0.14.4 enable

peer 10.0.14.4 advertise-community

#

route-policy match\_comm permit node 10

if-match community-filter 1

#

route-policy add\_comm permit node 10

apply community 200:1 additive

#

ip community-filter 1 permit 100

#

return

<R2>**display current-configuration**

[V200R007C00SPC600]

#

sysname R2

#

router id 10.0.2.2

#

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 10.0.25.2 255.255.255.0

#

interface LoopBack0

ip address 10.0.2.2 255.255.255.255

#

bgp 64513

peer 10.0.12.1 as-number 64513

peer 10.0.23.3 as-number 64514

peer 10.0.25.5 as-number 64515

#

ipv4-family unicast

undo synchronization

peer 10.0.12.1 enable

peer 10.0.12.1 next-hop-local

peer 10.0.12.1 advertise-community

peer 10.0.23.3 enable

peer 10.0.23.3 advertise-community

peer 10.0.25.5 enable

peer 10.0.25.5 advertise-community

#

return

<R3>**display current-configuration**

[V200R007C00SPC600]

#

sysname R3

#

router id 10.0.3.3

#

acl number 2001

rule 0 permit source 10.2.3.0 0.0.0.255

#

interface Serial2/0/0

link-protocol ppp

ip address 10.0.23.3 255.255.255.0

#

interface LoopBack0

ip address 10.0.3.3 255.255.255.255

#

interface LoopBack1

ip address 10.1.3.3 255.255.255.0

#

interface LoopBack2

ip address 10.2.3.3 255.255.255.0

#

bgp 64514

peer 10.0.23.2 as-number 64513

#

ipv4-family unicast

undo synchronization

network 10.1.3.0 255.255.255.0

network 10.2.3.0 255.255.255.0

peer 10.0.23.2 enable

peer 10.0.23.2 route-policy comm\_r3 export

peer 10.0.23.2 advertise-community

#

route-policy comm\_r3 permit node 10

if-match acl 2001

apply community 100

#

route-policy comm­­\_r3 permit node 20

#

return

<R4>**display current-configuration**

[V200R007C00SPC600]

#

sysname R4

#

router id 10.0.4.4

#

interface Serial1/0/0

link-protocol ppp

ip address 10.0.14.4 255.255.255.0

#

interface LoopBack0

ip address 10.0.4.4 255.255.255.255

#

bgp 64512

peer 10.0.14.1 as-number 64513

#

ipv4-family unicast

undo synchronization

peer 10.0.14.1 enable

peer 10.0.14.1 advertise-community

#

Return

<R5>**display current-configuration**

[V200R007C00SPC600]

#

sysname R5

#

router id 10.0.5.5

#

interface GigabitEthernet0/0/0

ip address 10.0.25.5 255.255.255.0

#

interface LoopBack0

ip address 10.0.5.5 255.255.255.255

#

interface LoopBack1

ip address 10.1.5.5 255.255.255.0

#

interface LoopBack2

ip address 10.2.5.5 255.255.255.0

#

interface LoopBack3

ip address 10.3.5.5 255.255.255.0

#

bgp 64515

peer 10.0.25.2 as-number 64513

#

ipv4-family unicast

undo synchronization

network 10.1.5.0 255.255.255.0

network 10.2.5.0 255.255.255.0

network 10.3.5.0 255.255.255.0

peer 10.0.25.2 enable

peer 10.0.25.2 route-policy comm\_r5 export

peer 10.0.25.2 advertise-community

#

route-policy comm\_r5 permit node 10

if-match acl 2000

apply community 100

#

route-policy comm\_r5 permit node 20

if-match acl 2001

apply community no-export

#

route-policy comm\_r5 permit node 30

if-match acl 2002

apply community no-advertise

#

return

实验 3-5 BGP多宿主

学习目的

* 掌握BGP多宿主环境中仅使用缺省路由时的配置方法
* 掌握BGP多宿主环境中使用缺省路由过滤部分路由的配置方法
* 掌握BGP多宿主环境中，仅使用BGP路由时的配置方法

## **拓扑图**

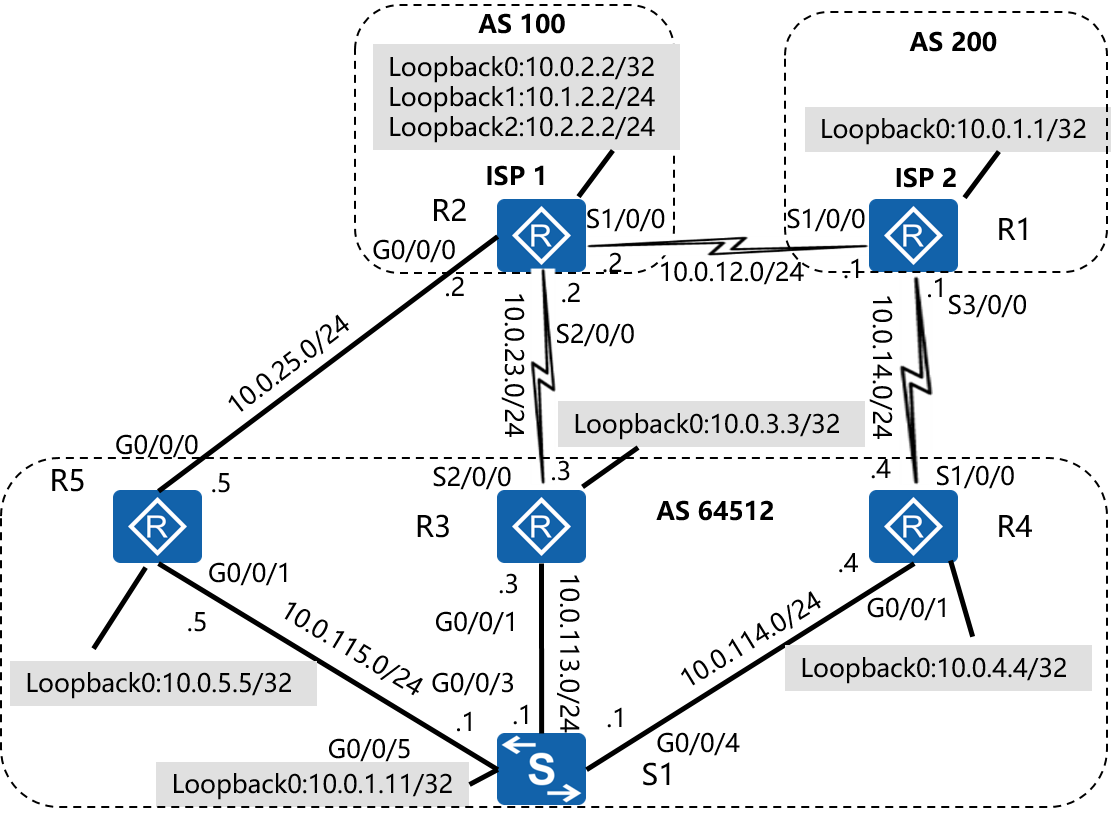


图3-5 BGP多宿主

## **场景**

你是公司的网络管理员。公司的网络采用了BGP协议接入了运营商ISP1。公司自己采用了私有的AS号64512，ISP1的AS号为100，公司从两台路由器分别接入ISP1。起初公司采用默认路由的方式通过运营商接入Internet，随着公司的发展，这种默认路由的接入方式已不能满足选路的需求，你需要把一部分Internet路由引入到公司的AS中。一段时间以后，公司又租用了一条线路接入到ISP2，ISP2的AS号为200。最终公司实现了由BGP选路的多宿主网络。

学习任务

1. 基础配置与IP编址

给所有路由器配置物理接口及Loopback接口的IP地址和掩码。注意各Loopback 0接口均使用32位掩码。

<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 Serial 3/0/0

[R1-Serial3/0/0]ip address 10.0.14.1 24

[R1-Serial3/0/0]quit

[R1]interface loopback 0

[R1-LoopBack0]ip address 10.0.1.1 32

[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 10.0.25.2 24

[R2-GigabitEthernet0/0/0]quit

[R2]interface loopback 0

[R2-LoopBack0]ip address 10.0.2.2 32

[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 GigabitEthernet 0/0/1

[R3-GigabitEthernet0/0/1]ip address 10.0.113.3 24

[R3-GigabitEthernet0/0/1]quit

[R3]interface loopback 0

[R3-LoopBack0]ip address 10.0.3.3 32

[R3-LoopBack0]quit

<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]quit

[R4]interface GigabitEthernet 0/0/1

[R4-GigabitEthernet0/0/1]ip address 10.0.114.4 24

[R4-GigabitEthernet0/0/1]quit

[R4]interface LoopBack 0

[R4-LoopBack0]ip address 10.0.4.4 32

[R4-LoopBack0]quit

<R5>system-view

Enter system view, return user view with Ctrl+Z.

[R5]interface GigabitEthernet 0/0/0

[R5-GigabitEthernet0/0/0]ip address 10.0.25.5 24

[R5-GigabitEthernet0/0/0]quit

[R5]interface GigabitEthernet 0/0/1

[R5-GigabitEthernet0/0/1]ip address 10.0.115.5 24

[R5-GigabitEthernet0/0/1]quit

[R5]interface loopback 0

[R5-LoopBack0]ip address 10.0.5.5 32

[R5-LoopBack0]quit

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=33 ms

--- 10.0.14.4 ping statistics ---

1 packet(s) transmitted

1 packet(s) received

0.00% packet loss

round-trip min/avg/max = 33/33/33 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=34 ms

--- 10.0.12.2 ping statistics ---

1 packet(s) transmitted

1 packet(s) received

0.00% packet loss

round-trip min/avg/max = 34/34/34 ms

<R2>ping -c 1 10.0.25.5

PING 10.0.25.5: 56 data bytes, press CTRL\_C to break

Reply from 10.0.25.5: bytes=56 Sequence=1 ttl=255 time=13 ms

--- 10.0.25.5 ping statistics ---

1 packet(s) transmitted

1 packet(s) received

0.00% packet loss

round-trip min/avg/max = 13/13/13 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=39 ms

--- 10.0.23.3 ping statistics ---

1 packet(s) transmitted

1 packet(s) received

0.00% packet loss

round-trip min/avg/max = 39/39/39 ms

1. 配置IGP及BGP

在AS 64512内部使用OSPF作为IGP，所有设备属于区域0。

R3的G0/0/1和Loopback 0连接的运行OSPF。

[R3]router id 10.0.3.3

[R3]ospf 1

[R3-ospf-1]area 0

[R3-ospf-1-area-0.0.0.0]network 10.0.113.3 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]quit

R4的G0/0/1和Loopback 0连接的网段运行OSPF。

[R4]router id 10.0.4.4

[R4]ospf 1

[R4-ospf-1]area 0

[R4-ospf-1-area-0.0.0.0]network 10.0.114.4 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]quit

[R4-ospf-1]quit

R5的G0/0/1和Loopback 0连接的网段运行OSPF，

[R5]router id 10.0.5.5

[R5]ospf 1

[R5-ospf-1]area 0

[R5-ospf-1-area-0.0.0.0]network 10.0.115.5 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]quit

[R5-ospf-1]quit

在S1上创建Vlan13，配置Vlanif地址与R3进行互联。

创建Vlan14，配置Vlanif地址与R4进行互联。

创建Vlan15，配置Vlanif地址与R5进行互联。

互联接口使用Access模式，Vlanif 13、Vlanif 14 、Vlanif 15和Loopback 0连接的网段运行OSPF。

[S1]vlan batch 13 to 15

[S1]interface vlan 13

[S1-Vlanif13]ip address 10.0.113.1 255.255.255.0

[S1-Vlanif13]quit

[S1]interface vlan 14

[S1-Vlanif14]ip address 10.0.114.1 255.255.255.0

[S1-Vlanif14]quit

[S1]interface vlan 15

[S1-Vlanif15]ip address 10.0.115.1 255.255.255.0

[S1-Vlanif15]quit

[S1]interface GigabitEthernet 0/0/3

[S1-GigabitEthernet0/0/3]port link-type access

[S1-GigabitEthernet0/0/3]port default vlan 13

[S1-GigabitEthernet0/0/3]quit

[S1]interface GigabitEthernet 0/0/4

[S1-GigabitEthernet0/0/4]port link-type access

[S1-GigabitEthernet0/0/4]port default vlan 14

[S1-GigabitEthernet0/0/4]quit

[S1]interface GigabitEthernet 0/0/5

[S1-GigabitEthernet0/0/5]port link-type access

[S1-GigabitEthernet0/0/5]port default vlan 15

[S1-GigabitEthernet0/0/5]quit

[S1]interface loopback 0

[S1-LoopBack0]ip address 10.0.1.11 32

[S1-LoopBack0]quit

[S1]router id 10.0.1.11

[S1]ospf 1

[S1-ospf-1]area 0

[S1-ospf-1-area-0.0.0.0]network 10.0.113.1 0.0.0.0

[S1-ospf-1-area-0.0.0.0]network 10.0.114.1 0.0.0.0

[S1-ospf-1-area-0.0.0.0]network 10.0.115.1 0.0.0.0

[S1-ospf-1-area-0.0.0.0]network 10.0.1.11 0.0.0.0

[S1-ospf-1-area-0.0.0.0]quit

[S1-ospf-1]quit

检查是否学习到其他设备的Loopback 0接口连接网段的路由。

<R3>display ip routing-table

Route Flags: R - relay, D - download to fib

----------------------------------------------------------------------------

Routing Tables: Public

Destinations : 17 Routes : 17

Destination/Mask Proto Pre Cost Flags NextHop Interface

10.0.1.11/32 OSPF 10 1 D 10.0.113.1 GigabitEthernet0/0/1

10.0.3.3/32 Direct 0 0 D 127.0.0.1 LoopBack0

10.0.4.4/32 OSPF 10 2 D 10.0.113.1 GigabitEthernet0/0/1

10.0.5.5/32 OSPF 10 2 D 10.0.113.1 GigabitEthernet0/0/1

10.0.23.0/24 Direct 0 0 D 10.0.23.3 Serial2/0/0

10.0.23.2/32 Direct 0 0 D 10.0.23.2 Serial2/0/0

10.0.23.3/32 Direct 0 0 D 127.0.0.1 Serial2/0/0

10.0.23.255/32 Direct 0 0 D 127.0.0.1 Serial2/0/0

10.0.113.0/24 Direct 0 0 D 10.0.113.3 GigabitEthernet0/0/1

10.0.113.3/32 Direct 0 0 D 127.0.0.1 GigabitEthernet0/0/1

10.0.113.255/32 Direct 0 0 D 127.0.0.1 GigabitEthernet0/0/1

10.0.114.0/24 OSPF 10 2 D 10.0.113.1 GigabitEthernet0/0/1

10.0.115.0/24 OSPF 10 2 D 10.0.113.1 GigabitEthernet0/0/1

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

127.255.255.255/32Direct 0 0 D 127.0.0.1 InLoopBack0

255.255.255.255/32Direct 0 0 D 127.0.0.1 InLoopBack0

<R4>display ip routing-table

Route Flags: R - relay, D - download to fib

----------------------------------------------------------------------------

Routing Tables: Public

Destinations : 17 Routes : 17

Destination/Mask Proto Pre Cost Flags NextHop Interface

10.0.1.11/32 OSPF 10 1 D 10.0.114.1 GigabitEthernet0/0/1

10.0.3.3/32 OSPF 10 2 D 10.0.114.1 GigabitEthernet0/0/1

10.0.4.4/32 Direct 0 0 D 127.0.0.1 LoopBack0

10.0.5.5/32 OSPF 10 2 D 10.0.114.1 GigabitEthernet0/0/1

10.0.14.0/24 Direct 0 0 D 10.0.14.4 Serial1/0/0

10.0.14.1/32 Direct 0 0 D 10.0.14.1 Serial1/0/0

10.0.14.4/32 Direct 0 0 D 127.0.0.1 Serial1/0/0

10.0.14.255/32 Direct 0 0 D 127.0.0.1 Serial1/0/0

10.0.113.0/24 OSPF 10 2 D 10.0.114.1 GigabitEthernet0/0/1

10.0.114.0/24 Direct 0 0 D 10.0.114.4 GigabitEthernet0/0/1

10.0.114.4/32 Direct 0 0 D 127.0.0.1 GigabitEthernet0/0/1

10.0.114.255/32 Direct 0 0 D 127.0.0.1 GigabitEthernet0/0/1

10.0.115.0/24 OSPF 10 2 D 10.0.114.1 GigabitEthernet0/0/1

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

127.255.255.255/32Direct 0 0 D 127.0.0.1 InLoopBack0

255.255.255.255/32Direct 0 0 D 127.0.0.1 InLoopBack0

<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

10.0.1.11/32 OSPF 10 1 D 10.0.115.1 GigabitEthernet0/0/1

10.0.3.3/32 OSPF 10 2 D 10.0.115.1 GigabitEthernet0/0/1

10.0.4.4/32 OSPF 10 2 D 10.0.115.1 GigabitEthernet0/0/1

10.0.5.5/32 Direct 0 0 D 127.0.0.1 LoopBack0

10.0.25.0/24 Direct 0 0 D 10.0.25.5 GigabitEthernet0/0/0

10.0.25.5/32 Direct 0 0 D 127.0.0.1 GigabitEthernet0/0/0

10.0.25.255/32 Direct 0 0 D 127.0.0.1 GigabitEthernet0/0/0

10.0.113.0/24 OSPF 10 2 D 10.0.115.1 GigabitEthernet0/0/1

10.0.114.0/24 OSPF 10 2 D 10.0.115.1 GigabitEthernet0/0/1

10.0.115.0/24 Direct 0 0 D 10.0.115.5 GigabitEthernet0/0/1

10.0.115.5/32 Direct 0 0 D 127.0.0.1 GigabitEthernet0/0/1

10.0.115.255/32 Direct 0 0 D 127.0.0.1 GigabitEthernet0/0/1

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

127.255.255.255/32Direct 0 0 D 127.0.0.1 InLoopBack0

255.255.255.255/32Direct 0 0 D 127.0.0.1 InLoopBack0

[S1]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

10.0.1.11/32 Direct 0 0 D 127.0.0.1 LoopBack0

10.0.3.3/32 OSPF 10 1 D 10.0.113.3 Vlanif13

10.0.4.4/32 OSPF 10 1 D 10.0.114.4 Vlanif14

10.0.5.5/32 OSPF 10 1 D 10.0.115.5 Vlanif15

10.0.113.0/24 Direct 0 0 D 10.0.113.1 Vlanif13

10.0.113.1/32 Direct 0 0 D 127.0.0.1 Vlanif13

10.0.114.0/24 Direct 0 0 D 10.0.114.1 Vlanif14

10.0.114.1/32 Direct 0 0 D 127.0.0.1 Vlanif14

10.0.115.0/24 Direct 0 0 D 10.0.115.1 Vlanif15

10.0.115.1/32 Direct 0 0 D 127.0.0.1 Vlanif15

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

在R2、R3、R5上配置EBGP。

AS的规划如图所示，EBGP全部使用物理接口地址建立对等体关系。S1不运行BGP。

[R2]router id 10.0.2.2

[R2]bgp 100

[R2-bgp]peer 10.0.25.5 as-number 64512

[R2-bgp]peer 10.0.23.3 as-number 64512

[R2-bgp]quit

[R3]bgp 64512

[R3-bgp]peer 10.0.23.2 as-number 100

[R3-bgp]quit

[R5]bgp 64512

[R5-bgp]peer 10.0.25.2 as-number 100

[R5-bgp]quit

完成后检查BGP邻居是否完全建立。

[R2]display bgp peer

BGP local router ID : 10.0.2.2

Local AS number : 100

Total number of peers : 2 Peers in established state : 2

Peer V AS MsgRcvd MsgSent OutQ Up/Down State PrefRcv

10.0.23.3 4 64512 7 9 0 00:05:55 Established 0

10.0.25.5 4 64512 6 7 0 00:04:17 Established 0

[R3]display bgp peer

BGP local router ID : 10.0.3.3

Local AS number : 64512

Total number of peers : 1 Peers in established state : 1

Peer V AS MsgRcvd MsgSent OutQ Up/Down State PrefRcv

10.0.23.2 4 100 8 8 0 00:06:09 Established 0

<R5>display bgp peer

BGP local router ID : 10.0.5.5

Local AS number : 64512

Total number of peers : 1 Peers in established state : 1

Peer V AS MsgRcvd MsgSent OutQ Up/Down State PrefRcv

10.0.25.2 4 100 7 7 0 00:05:31 Established 0

1. 配置仅使用缺省路由归属到单个ISP

默认情况下，BGP的负载分担是关闭的。在所有的路由器上打开负载分担，设置为最大4条路径。

[R1]router id 10.0.1.1

[R1]bgp 200

[R1-bgp]maximum load-balancing 4

[R1-bgp]quit

[R2]bgp 100

[R2-bgp]maximum load-balancing 4

[R2-bgp]quit

[R3]bgp 64512

[R3-bgp]maximum load-balancing 4

[R3-bgp]quit

[R4]bgp 64512

[R4-bgp]maximum load-balancing 4

[R4-bgp]quit

[R5]bgp 64512

[R5-bgp]maximum load-balancing 4

[R5-bgp]quit

在R2上创建Loopback 1和Loopback 2，地址分别为10.1.2.2/24和10.2.2.2/24。使用**network**命令将这两个网段发布到BGP中，

[R2]interface LoopBack 1

[R2-LoopBack1]ip address 10.1.2.2 24

[R2-LoopBack1]quit

[R2]interface LoopBack 2

[R2-LoopBack2]ip address 10.2.2.2 24

[R2-LoopBack2]quit

[R2]bgp 100

[R2-bgp]network 10.1.2.0 255.255.255.0

[R2-bgp]network 10.2.2.0 255.255.255.0

[R2-bgp]quit

在R3和R5上分别检查是否学习到该路由。

[R3]display bgp routing-table

BGP Local router ID is 10.0.3.3

Status codes: \* - valid, > - best, d - damped,

h - history, i - internal, s - suppressed, S - Stale

Origin : i - IGP, e - EGP, ? - incomplete

Total Number of Routes: 2

Network NextHop MED LocPrf PrefVal Path/Ogn

\*> 10.1.2.0/24 10.0.23.2 0 0 100i

\*> 10.2.2.0/24 10.0.23.2 0 0 100i

<R5>display bgp routing-table

BGP Local router ID is 10.0.5.5

Status codes: \* - valid, > - best, d - damped,

h - history, i - internal, s - suppressed, S - Stale

Origin : i - IGP, e - EGP, ? - incomplete

Total Number of Routes: 2

Network NextHop MED LocPrf PrefVal Path/Ogn

\*> 10.1.2.0/24 10.0.25.2 0 0 100i

\*> 10.2.2.0/24 10.0.25.2 0 0 100i

在这里，R3接入到ISP1的线路为主用线路，R5接入到ISP1的线路为备用线路。在R3和R5上分别将OSPF的路由通过**import-route**命令引入进BGP，

[R3]bgp 64512

[R3-bgp]import-route ospf 1

[R3-bgp]quit

[R5]bgp 64512

[R5-bgp]import-route ospf 1

[R5-bgp]quit

在R3和R5上向区域0内强制发布默认路由，并采用第一类外部路由类型发布。设置R3发布的默认路由cost为20，R5发布的默认路由cost为40。

[R3]ospf 1

[R3-ospf-1]default-route-advertise always cost 20 type 1

[R3-ospf-1]quit

[R5]ospf 1

[R5-ospf-1]default-route-advertise always cost 40 type 1

[R5-ospf-1]quit

在S1上查看路由表。

[S1]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

0.0.0.0/0 O\_ASE 150 21 D 10.0.113.3 Vlanif13

10.0.1.11/32Direct 0 0 D 127.0.0.1 LoopBack0

10.0.3.3/32 OSPF 10 1 D 10.0.113.3 Vlanif13

10.0.4.4/32 OSPF 10 1 D 10.0.114.4 Vlanif14

10.0.5.5/32 OSPF 10 1 D 10.0.115.5 Vlanif15

10.0.113.0/24 Direct 0 0 D 10.0.113.1 Vlanif13

10.0.113.1/32 Direct 0 0 D 127.0.0.1 Vlanif13

10.0.114.0/24 Direct 0 0 D 10.0.114.1 Vlanif14

10.0.114.1/32 Direct 0 0 D 127.0.0.1 Vlanif14

10.0.115.0/24 Direct 0 0 D 10.0.115.1 Vlanif15

10.0.115.1/32 Direct 0 0 D 127.0.0.1 Vlanif15

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

在S1上查看到达地址10.1.2.2经过的路径。

缺省情况下，设备的ICMP端口不可达报文的发送功能处于未使能状态，所以我们首先在R2上执行命令**icmp port-unreachable send**，使能设备的ICMP端口不可达报文的发送功能。

[R2]icmp port-unreachable send

[S1]tracert 10.1.2.2

traceroute to 10.1.2.2(10.1.2.2), max hops: 30 ,packet length: 40,press CTRL\_C to break

1 10.0.113.3 3 ms 2 ms 48 ms

2 10.1.2.2 19 ms 19 ms 18 ms

此时S1选择使用从R3上学习到的默认路由，即通过主用线路访问10.1.2.2。

关闭R3的S2/0/0，模拟公司到运营商的线路故障。

[R3]interface s2/0/0

[R3-Serial2/0/0]shutdown

[R3-Serial2/0/0]quit

待路由收敛后在S1上查看路由表。并检查到10.1.2.2的连通性。

[S1]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

0.0.0.0/0 O\_ASE 150 21 D 10.0.113.3 Vlanif13

10.0.1.11/32 Direct 0 0 D 127.0.0.1 LoopBack0

10.0.3.3/32 OSPF 10 1 D 10.0.113.3 Vlanif13

10.0.4.4/32 OSPF 10 1 D 10.0.114.4 Vlanif14

10.0.5.5/32 OSPF 10 1 D 10.0.115.5 Vlanif15

10.0.113.0/24 Direct 0 0 D 10.0.113.1 Vlanif13

10.0.113.1/32 Direct 0 0 D 127.0.0.1 Vlanif13

10.0.114.0/24 Direct 0 0 D 10.0.114.1 Vlanif14

10.0.114.1/32 Direct 0 0 D 127.0.0.1 Vlanif14

10.0.115.0/24 Direct 0 0 D 10.0.115.1 Vlanif15

10.0.115.1/32 Direct 0 0 D 127.0.0.1 Vlanif15

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

[S1]ping 10.1.2.2

PING 10.1.2.2: 56 data bytes, press CTRL\_C to break

Request time out

Request time out

Request time out

Request time out

Request time out

--- 10.1.2.2 ping statistics ---

5 packet(s) transmitted

0 packet(s) received

100.00% packet loss

可以观察到S1的路由表没有变化，仍旧是通过R3访问目标网络。

由于是上联链路故障，而下联链路中S1是通过比较R3与R5下发默认路由的cost值的大小，最终选择R3下发的默认路由，二者互不影响，所以网络无法正常工作。

恢复R3的S2/0/0，关闭R3的G0/0/1，模拟R3的下联线路故障。

查看路由收敛情况，并检查连通性。

[R3]interface s2/0/0

[R3-Serial2/0/0]undo shutdown

[R3-Serial2/0/0]quit

[R3]interface g0/0/1

[R3-GigabitEthernet0/0/1]shutdown

[R3-GigabitEthernet0/0/1]quit

[S1]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

0.0.0.0/01 O\_ASE 150 41 D 10.0.115.5 Vlanif15

10.0.1.11/32 Direct 0 0 D 127.0.0.1 LoopBack0

10.0.4.4/32 OSPF 10 1 D 10.0.114.4 Vlanif14

10.0.5.5/32 OSPF 10 1 D 10.0.115.5 Vlanif15

10.0.113.0/24 Direct 0 0 D 10.0.114.1 Vlanif13

10.0.113.1/32 Direct 0 0 D 127.0.0.1 Vlanif13

10.0.114.0/24 Direct 0 0 D 10.0.114.1 Vlanif14

10.0.114.1/32 Direct 0 0 D 127.0.0.1 Vlanif14

10.0.115.0/24 Direct 0 0 D 10.0.115.1 Vlanif15

10.0.115.1/32 Direct 0 0 D 127.0.0.1 Vlanif15

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

[S1]ping 10.1.2.2

PING 10.1.2.2: 56 data bytes, press CTRL\_C to break

Reply from 10.1.2.2: bytes=56 Sequence=1 ttl=254 time=1 ms

Reply from 10.1.2.2: bytes=56 Sequence=2 ttl=254 time=1 ms

Reply from 10.1.2.2: bytes=56 Sequence=3 ttl=254 time=1 ms

Reply from 10.1.2.2: bytes=56 Sequence=4 ttl=254 time=1 ms

Reply from 10.1.2.2: bytes=56 Sequence=5 ttl=254 time=1 ms

--- 10.1.2.2 ping statistics ---

5 packet(s) transmitted

5 packet(s) received

0.00% packet loss

round-trip min/avg/max = 1/1/1 ms

此时S1通过R5学习到默认路由，即通过备用链路访问目标网络。

恢复R3的G0/0/1端口。

[R3]interface g0/0/1

[R3-GigabitEthernet0/0/1]undo shutdown

[R3-GigabitEthernet0/0/1]quit

1. 配置使用缺省路由和部分过滤路由归属到单个ISP

配置R3、R4、R5到S1的IBGP邻居关系，并添加**next-hop-local**参数，保证S1能学习到从ISP发来的路由更新消息。

[R3]bgp 64512

[R3-bgp]peer 10.0.113.1 as-number 64512

[R3-bgp]peer 10.0.113.1 next-hop-local

[R3-bgp]quit

[R4]bgp 64512

[R4-bgp]peer 10.0.114.1 as-number 64512

[R4-bgp]peer 10.0.114.1 next-hop-local

[R4-bgp]quit

[R5]bgp 64512

[R5-bgp]peer 10.0.115.1 as-number 64512

[R5-bgp]peer 10.0.115.1 next-hop-local

[R5-bgp]quit

[S1]bgp 64512

[S1-bgp]peer 10.0.113.3 as-number 64512

[S1-bgp]peer 10.0.114.4 as-number 64512

[S1-bgp]peer 10.0.115.5 as-number 64512

[S1-bgp]quit

观察S1是否学习到了10.1.2.0/24和10.2.2.0/24。

[S1]display ip routing-table

Route Flags: R - relay, D - download to fib

----------------------------------------------------------------------------

Routing Tables: Public

Destinations : 15 Routes : 15

Destination/Mask Proto Pre Cost Flags NextHop Interface

0.0.0.0/0 O\_ASE 150 21 D 10.0.113.3 Vlanif13

10.0.1.11/32 Direct 0 0 D 127.0.0.1 LoopBack0

10.0.3.3/32 OSPF 10 1 D 10.0.113.3 Vlanif13

10.0.4.4/32 OSPF 10 1 D 10.0.114.4 Vlanif14

10.0.5.5/32 OSPF 10 1 D 10.0.115.5 Vlanif15

10.0.113.0/24 Direct 0 0 D 10.0.113.1 Vlanif13

10.0.113.1/32 Direct 0 0 D 127.0.0.1 Vlanif13

10.0.114.0/24 Direct 0 0 D 10.0.114.1 Vlanif14

10.0.114.1/32 Direct 0 0 D 127.0.0.1 Vlanif14

10.0.115.0/24 Direct 0 0 D 10.0.115.1 Vlanif15

10.0.115.1/32 Direct 0 0 D 127.0.0.1 Vlanif15

10.1.2.0/24 IBGP 255 0 RD 10.0.113.3 Vlanif13

10.2.2.0/24 IBGP 255 0 RD 10.0.113.3 Vlanif13

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

这时我们希望通过BGP来影响选路，在R3上添加路由策略**policy\_r3**，过滤掉10.1.2.0/24。

[R3]acl number 2001

[R3-acl-basic-2001]rule 0 permit source 10.1.2.0 0.0.0.255

[R3-acl-basic-2001]quit

[R3]route-policy policy\_r3 deny node 10

[R3-route-policy]if-match acl 2001

[R3-route-policy]quit

[R3]route-policy policy\_r3 permit node 20

[R3-route-policy]quit

[R3]bgp 64512

[R3-bgp]peer 10.0.113.1 route-policy policy\_r3 export

[R3-bgp]quit

在R5上添加路由策略**policy\_r5**，过滤掉10.2.2.0/24，

[R5]acl number 2001

[R5-acl-basic-2001]rule 0 permit source 10.2.2.0 0.0.0.255

[R5-acl-basic-2001]quit

[R5]route-policy policy\_r5 deny node 10

[R5-route-policy]if-match acl 2001

[R5-route-policy]quit

[R5]route-policy policy\_r5 permit node 20

[R5-route-policy]quit

[R5]bgp 64512

[R5-bgp]peer 10.0.115.1 route-policy policy\_r5 export

[R5-bgp]quit

在S1上观察路由表的变化。

[S1]display ip routing-table

Route Flags: R - relay, D - download to fib

----------------------------------------------------------------------------

Routing Tables: Public

Destinations : 15 Routes : 15

Destination/Mask Proto Pre Cost Flags NextHop Interface

0.0.0.0/0 O\_ASE 150 21 D 10.0.113.3 Vlanif13

10.0.1.11/32 Direct 0 0 D 127.0.0.1 LoopBack0

10.0.3.3/32 OSPF 10 1 D 10.0.113.3 Vlanif13

10.0.4.4/32 OSPF 10 1 D 10.0.114.4 Vlanif14

10.0.5.5/32 OSPF 10 1 D 10.0.115.5 Vlanif15

10.0.113.0/24 Direct 0 0 D 10.0.113.1 Vlanif13

10.0.113.1/32 Direct 0 0 D 127.0.0.1 Vlanif13

10.0.114.0/24 Direct 0 0 D 10.0.114.1 Vlanif14

10.0.114.1/32 Direct 0 0 D 127.0.0.1 Vlanif14

10.0.115.0/24 Direct 0 0 D 10.0.115.1 Vlanif15

10.0.115.1/32 Direct 0 0 D 127.0.0.1 Vlanif15

10.1.2.0/24 IBGP 255 0 RD 10.0.115.5 Vlanif15

10.2.2.0/24 IBGP 255 0 RD 10.0.113.3 Vlanif13

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

此时到达网络10.1.2.0/24的下一跳是R5，到达网络10.2.2.0/24的下一跳是R3。

关闭R3的S2/0/0。

[R3]interface s2/0/0

[R3-Serial2/0/0]shutdown

[R3-Serial2/0/0]quit

观察S1的路由变化，测试到10.1.2.2的连通性。

[S1]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

0.0.0.0/0 O\_ASE 150 21 D 10.0.113.3 Vlanif13

10.0.1.11/32 Direct 0 0 D 127.0.0.1 LoopBack0

10.0.3.3/32 OSPF 10 1 D 10.0.113.3 Vlanif13

10.0.4.4/32 OSPF 10 1 D 10.0.114.4 Vlanif14

10.0.5.5/32 OSPF 10 1 D 10.0.115.5 Vlanif15

10.0.113.0/24 Direct 0 0 D 10.0.113.1 Vlanif13

10.0.113.1/32 Direct 0 0 D 127.0.0.1 Vlanif13

10.0.114.0/24 Direct 0 0 D 10.0.114.1 Vlanif14

10.0.114.1/32 Direct 0 0 D 127.0.0.1 Vlanif14

10.0.115.0/24 Direct 0 0 D 10.0.115.1 Vlanif15

10.0.115.1/32 Direct 0 0 D 127.0.0.1 Vlanif15

10.1.2.0/24 IBGP 255 0 RD 10.0.115.5 Vlanif15

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

此时只有路由10.1.2.0/24，因为R5上做了策略过滤掉了路由10.2.2.0/24。

[S1]ping 10.1.2.2

PING 10.1.2.2: 56 data bytes, press CTRL\_C to break

Reply from 10.1.2.2: bytes=56 Sequence=1 ttl=254 time=1 ms

Reply from 10.1.2.2: bytes=56 Sequence=2 ttl=254 time=1 ms

Reply from 10.1.2.2: bytes=56 Sequence=3 ttl=254 time=1 ms

Reply from 10.1.2.2: bytes=56 Sequence=4 ttl=254 time=1 ms

Reply from 10.1.2.2: bytes=56 Sequence=5 ttl=254 time=1 ms

--- 10.1.2.2 ping statistics ---

5 packet(s) transmitted

5 packet(s) received

0.00% packet loss

round-trip min/avg/max = 1/1/1 ms

恢复R3的S2/0/0接口。

[R3]interface s2/0/0

[R3-Serial2/0/0]undo shutdown

[R3-Serial2/0/0]quit

1. 配置使用BGP路由归属到多个ISP

这时公司又申请了一条Internet线路接入ISP2，为了采用BGP来进行路径选择，这里先删除前面试验中OSPF发布的默认路由。

[R3]ospf 1

[R3-ospf-1]undo default-route-advertise

[R3-ospf-1]quit

[R5]ospf 1

[R5-ospf-1]undo default-route-advertise

[R5-ospf-1]quit

删除R3和R5上对路由进行过滤的策略。

[R3]bgp 64512

[R3-bgp]undo peer 10.0.113.1 route-policy policy\_r3 export

[R3-bgp]quit

[R3]undo route-policy policy\_r3

[R5]bgp 64512

[R5-bgp]undo peer 10.0.115.1 route-policy policy\_r5 export

[R5-bgp]quit

[R5]undo route-policy policy\_r5

删除R3和R5上将OSPF路由引入到BGP中的命令。

[R3]bgp 64512

[R3-bgp]undo import-route ospf 1

[R3-bgp]quit

[R5]bgp 64512

[R5-bgp]undo import-route ospf 1

[R5-bgp]quit

在R1和R2、R1和R4之间建立EBGP邻居关系，使ISP2也能传送10.1.2.0/24和10.2.2.0/24。

[R1]bgp 200

[R1-bgp]peer 10.0.12.2 as-number 100

[R1-bgp]peer 10.0.14.4 as-number 64512

[R1-bgp]quit

[R2]bgp 100

[R2-bgp]peer 10.0.12.1 as-number 200

[R2-bgp]quit

[R4]bgp 64512

[R4-bgp]peer 10.0.14.1 as-number 200

[R4-bgp]quit

在S1上观察路由10.1.2.0/24和10.2.2.0/24，注意当前的选路原则。

[S1]display bgp routing-table

BGP Local router ID is 10.0.1.11

Status codes: \* - valid, > - best, d - damped,

h - history, i - internal, s - suppressed, S - Stale

Origin : i - IGP, e - EGP, ? - incomplete

Total Number of Routes: 6

Network NextHop MED LocPrf PrefVal Path/Ogn

\*>i 10.1.2.0/24 10.0.113.3 0 100 0 100i

\* i 10.0.115.5 0 100 0 100i

\* i 10.0.114.4 100 0 200 100i

\*>i 10.2.2.0/24 10.0.113.3 0 100 0 100i

\* i 10.0.115.5 0 100 0 100i

\* i 10.0.114.4 100 0 200 100i

现在我们希望公司使用连接到ISP2的新线路来访问网络10.2.2.0/24。在R4上设置路由策略**policy\_r4**，将该路由的本地优先属性改为150。

[R4]acl number 2001

[R4-acl-basic-2001]rule 0 permit source 10.2.2.0 0.0.0.255

[R4-acl-basic-2001]quit

[R4]route-policy policy\_r4 permit node 10

[R4-route-policy]if-match acl 2001

[R4-route-policy]apply local-preference 150

[R4-route-policy]quit

[R4]route-policy policy\_r4 permit node 20

[R4-route-policy]quit

将该路由策略对S1发布。

[R4]bgp 64512

[R4-bgp]peer 10.0.114.1 route-policy policy\_r4 export

[R4-bgp]quit

在S1上检查BGP路由表。

[S1]display bgp routing-table

BGP Local router ID is 10.0.1.11

Status codes: \* - valid, > - best, d - damped,

h - history, i - internal, s - suppressed, S - Stale

Origin : i - IGP, e - EGP, ? - incomplete

Total Number of Routes: 6

Network NextHop MED LocPrf PrefVal Path/Ogn

\*>i 10.1.2.0/24 10.0.113.3 0 100 0 100i

\* i 10.0.115.5 0 100 0 100i

\* i 10.0.114.4 100 0 200 100i

\*>i 10.2.2.0/24 10.0.114.4 150 0 200 100i

\* i 10.0.113.3 0 100 0 100i

\* i 10.0.115.5 0 100 0 100i

此时S1使用通过R4连接的ISP2获得路由到达网段10.2.2.0/24。

关闭R4的S1/0/0端口模拟故障。

[R4]interface s1/0/0

[R4-Serial1/0/0]shutdown

[R4-Serial1/0/0]quit

查看S1上BGP路由表的变化。

[S1]display bgp routing-table

BGP Local router ID is 10.0.1.11

Status codes: \* - valid, > - best, d - damped,

h - history, i - internal, s - suppressed, S - Stale

Origin : i - IGP, e - EGP, ? - incomplete

Total Number of Routes: 4

Network NextHop MED LocPrf PrefVal Path/Ogn

\*>i 10.1.2.0/24 10.0.113.3 0 100 0 100i

\* i 10.0.115.5 0 100 0 100i

\*>i 10.2.2.0/24 10.0.113.3 0 100 0 100i

\* i 10.0.115.5 0 100 0 100i

此时S1通过R3所连接的ISP1获得路由10.1.2.0/24和10.2.2.0/24。

打开R4的S1/0/0接口。

[R4]interface s1/0/0

[R4-Serial1/0/0]undo shutdown

[R4-Serial1/0/0]quit

检查S1上的BGP路由表，查看是否恢复。

[S1]display bgp routing-table

BGP Local router ID is 10.0.1.11

Status codes: \* - valid, > - best, d - damped,

h - history, i - internal, s - suppressed, S - Stale

Origin : i - IGP, e - EGP, ? - incomplete

Total Number of Routes: 6

Network NextHop MED LocPrf PrefVal Path/Ogn

\*>i 10.1.2.0/24 10.0.113.3 0 100 0 100i

\* i 10.0.115.5 0 100 0 100i

\* i 10.0.114.4 100 0 200 100i

\*>i 10.2.2.0/24 10.0.114.4 150 0 200 100i

\* i 10.0.113.3 0 100 0 100i

\* i 10.0.115.5 0 100 0 100i

## **附加实验: 思考并验证**

思考在步骤三中，关闭R3的S2/0/0接口后，虽然公司到运营商的主用链路发生故障，但是此时R5与ISP1之间的备用链路仍然正常，该如何解决此时的连通问题？

在这个例子中，多归属到两个运营商，怎样实现对同一网段入流量的负载分担？

## **最终设备配置**

<R1>**display current-configuration**

[V200R007C00SPC600]

#

sysname R1

#

router id 10.0.1.1

#

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 10.0.1.1 255.255.255.255

#

bgp 200

peer 10.0.12.2 as-number 100

peer 10.0.14.4 as-number 64512

#

ipv4-family unicast

undo synchronization

maximum load-balancing 4

peer 10.0.12.2 enable

peer 10.0.14.4 enable

#

return

<R2>**display current-configuration**

[V200R007C00SPC600]

#

sysname R2

#

router id 10.0.2.2

#

icmp port-unreachable send

#

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 10.0.25.2 255.255.255.0

#

interface LoopBack0

ip address 10.0.2.2 255.255.255.255

#

interface LoopBack1

ip address 10.1.2.2 255.255.255.0

#

interface LoopBack2

ip address 10.2.2.2 255.255.255.0

#

bgp 100

peer 10.0.12.1 as-number 200

peer 10.0.23.3 as-number 64512

peer 10.0.25.5 as-number 64512

#

ipv4-family unicast

undo synchronization

network 10.1.2.0 255.255.255.0

network 10.2.2.0 255.255.255.0

maximum load-balancing 4

peer 10.0.12.1 enable

peer 10.0.23.3 enable

peer 10.0.25.5 enable

#

return

<R3>**display current-configuration**

[V200R007C00SPC600]

#

sysname R3

#

router id 10.0.3.3

#

acl number 2001

rule 0 permit source 10.1.2.0 0.0.0.255

#

interface Serial2/0/0

link-protocol ppp

ip address 10.0.23.3 255.255.255.0

#

interface GigabitEthernet0/0/1

ip address 10.0.113.3 255.255.255.0

#

interface LoopBack0

ip address 10.0.3.3 255.255.255.255

#

bgp 64512

peer 10.0.23.2 as-number 100

peer 10.0.113.1 as-number 64512

#

ipv4-family unicast

undo synchronization

maximum load-balancing 4

peer 10.0.23.2 enable

peer 10.0.113.1 enable

peer 10.0.113.1 next-hop-local

#

ospf 1

area 0.0.0.0

network 10.0.113.3 0.0.0.0

network 10.0.3.3 0.0.0.0

#

return

<R4>**display current-configuration**

[V200R007C00SPC600]

#

sysname R4

#

router id 10.0.4.4

#

interface Serial1/0/0

link-protocol ppp

ip address 10.0.14.4 255.255.255.0

#

interface GigabitEthernet0/0/1

ip address 10.0.114.4 255.255.255.0

#

interface LoopBack0

ip address 10.0.4.4 255.255.255.255

#

bgp 64512

peer 10.0.14.1 as-number 200

peer 10.0.114.1 as-number 64512

#

ipv4-family unicast

undo synchronization

maximum load-balancing 4

peer 10.0.14.1 enable

peer 10.0.114.1 enable

peer 10.0.114.1 route-policy policy\_r4 export

peer 10.0.114.1 next-hop-local

#

ospf 1

area 0.0.0.0

network 10.0.114.4 0.0.0.0

network 10.0.4.4 0.0.0.0

#

route-policy policy\_r4 permit node 10

if-match acl 2001

apply local-preference 150

route-policy policy\_r4 permit node 20

#

Return

<R5>**display current-configuration**

[V200R007C00SPC600]

#

sysname R5

#

router id 10.0.5.5

#

interface GigabitEthernet0/0/0

ip address 10.0.25.5 255.255.255.0

#

interface GigabitEthernet0/0/1

ip address 10.0.115.5 255.255.255.0

#

interface LoopBack0

ip address 10.0.5.5 255.255.255.255

#

bgp 64512

peer 10.0.25.2 as-number 100

peer 10.0.115.1 as-number 64512

#

ipv4-family unicast

undo synchronization

maximum load-balancing 4

peer 10.0.25.2 enable

peer 10.0.115.1 enable

peer 10.0.115.1 next-hop-local

#

ospf 1

area 0.0.0.0

network 10.0.115.5 0.0.0.0

network 10.0.5.5 0.0.0.0

#

return

<S1>**display current-configuration**

#

!Software Version V100R005C01SPC100

sysname S1

#

router id 10.0.1.11

#

interface Vlanif13

ip address 10.0.113.1 255.255.255.0

#

interface Vlanif14

ip address 10.0.114.1 255.255.255.0

#

interface Vlanif15

ip address 10.0.115.1 255.255.255.0

#

interface GigabitEthernet0/0/3

port link-type access

port default vlan 13

#

interface GigabitEthernet0/0/4

port link-type access

port default vlan 14

#

interface GigabitEthernet0/0/5

port link-type access

port default vlan 15

#

interface LoopBack0

ip address 10.0.1.11 255.255.255.255

#

bgp 64512

peer 10.0.113.3 as-number 64512

peer 10.0.114.4 as-number 64512

peer 10.0.115.5 as-number 64512

#

ipv4-family unicast

undo synchronization

peer 10.0.113.3 enable

peer 10.0.114.4 enable

peer 10.0.115.5 enable

#

ospf 1

area 0.0.0.0

network 10.0.113.1 0.0.0.0

network 10.0.114.1 0.0.0.0

network 10.0.115.1 0.0.0.0

network 10.0.1.11 0.0.0.0

#

return

实验 3-6 BGP故障排除

学习目的

* 掌握BGP邻居无法建立的故障排除
* 掌握BGP相关Debug命令的使用

## **拓扑图**

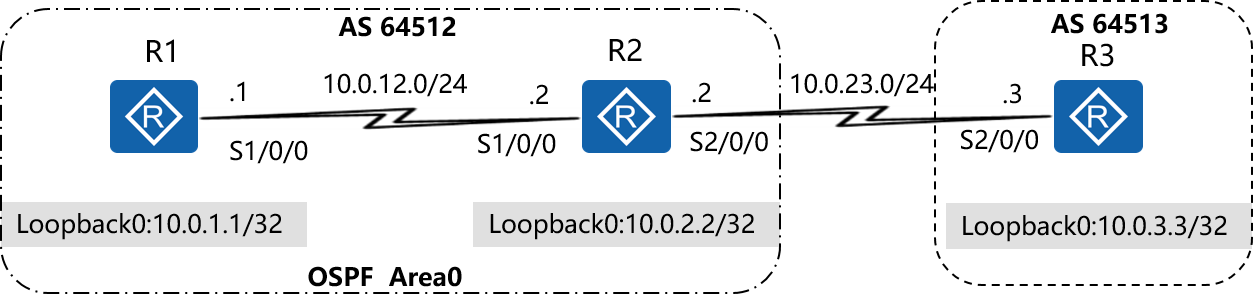


图3-6 BGP故障排除

## **场景**

你是公司的网络管理员。公司的网络采用了BGP协议作为路由协议。公司的网络由多个自治系统组成，不同的分支机构使用了不同的AS号。现在你已经完成公司网络的搭建工作，可是在配置BGP的过程中你遇到了不少问题，最后你通过故障排除的思想和方法，你成功的找到了各种错误，并进行了网络的故障排除。

学习任务

1. 基础配置与IP编址

首先给所有路由器配置物理接口及Loopback接口的IP地址和掩码，各Loopback接口均为32位掩码，地址的规划如拓扑图中所示。

<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 add 10.0.1.1 32

[R1-LoopBack0]quit

[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 LoopBack 0

[R2-LoopBack0]ip address 10.0.2.2 32

[R2-LoopBack0]quit

[R3]interface Serial 2/0/0

[R3-Serial2/0/0]ip address 10.0.23.3 24

[R3-Serial2/0/0]quit

[R3]interface LoopBack 0

[R3-LoopBack0]ip address 10.0.3.3 32

[R3-LoopBack0]quit

配置完成后，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=40 ms

--- 10.0.12.1 ping statistics ---

1 packet(s) transmitted

1 packet(s) received

0.00% packet loss

round-trip min/avg/max = 40/40/40 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=38 ms

--- 10.0.23.3 ping statistics ---

1 packet(s) transmitted

1 packet(s) received

0.00% packet loss

round-trip min/avg/max = 38/38/38 ms

结果显示直连链路连通性正常。

1. 配置IGP及BGP

在这个场景中，在AS 64512内部我们使用OSPF作为IGP，所有设备属于区域0。各路由器使用Loopback0的地址作为Router ID。R1的S1/0/0和Loopback 0所连接的网段运行OSPF。

[R1]router-id 10.0.1.1

[R1]ospf 1

[R1-ospf-1]area 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 10.0.1.1 0.0.0.0

[R1-ospf-1-area-0.0.0.0]quit

[R1-ospf-1]quit

R2的S1/0/0和Loopback 0所连接的网段运行OSPF。

[R2]router id 10.0.2.2

[R2]ospf 1

[R2-ospf-1]area 0

[R2-ospf-1-area-0.0.0.0]network 10.0.12.2 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]quit

配置完成以后检查R1到R2的Loopback0地址的连通性。

[R1]ping -c 1 -a 10.0.1.1 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=40 ms

--- 10.0.2.2 ping statistics ---

1 packet(s) transmitted

1 packet(s) received

0.00% packet loss

round-trip min/avg/max = 40/40/40 ms

在R1、R2之间配置IBGP，在R2和R3之间配置EBGP，均使用Loopback地址建立对等体关系，为保证路由信息的正常传递，在R2上针对R1配置**Next-hop-local**，在R3上你错误的将对等体10.0.2.2的AS号配置为64514了。

[R1]bgp 64512

[R1-bgp]peer 10.0.2.2 as-number 64512

[R1-bgp]quit

[R2]bgp 64512

[R2-bgp]peer 10.0.1.1 as-number 64512

[R2-bgp]peer 10.0.1.1 next-hop-local

[R2-bgp]peer 10.0.3.3 as-number 64513

[R2-bgp]quit

[R3]router id 10.0.3.3

[R3]bgp 64513

[R3-bgp]peer 10.0.2.2 as-number 64514

[R3-bgp]quit

1. 排除对等建立的故障

在完成上面的配置以后，你发现路由器之间对等体关系并没有建立起来，首先在R2上观察对等体关系。

[R2]display bgp peer

BGP local router ID : 10.0.2.2

Local AS number : 64512

Total number of peers : 2 Peers in established state : 0

Peer V AS MsgRcvd MsgSent OutQ Up/Down State PrefRcv

10.0.1.1 4 64512 0 0 0 00:05:36 Active 0

10.0.3.3 4 64513 0 0 0 00:05:21 Idle 0

从上面的输出中我们可以看到，10.0.1.1的状态为Active，10.0.3.3的状态为Idle。BGP对等体关系建立正常的情况下，State的状态应为**Established**。长时间停留在其他状态均为故障的现象，下面将逐步排除各种故障。

一般情况下，当对等体IP地址对于本地路由器是不可达的时，对等体状态会显示为Idle。也就是路由器根本没有向对等体发起TCP连接。当对等体IP地址可达，但TCP连接建立存在问题时，就可以看到对等体之间停留在Active状态。

首先考虑R2与R3之间的对等体关系的问题，先检查R2和R3之间Loopback地址之间的连通性。

[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

Request time out

--- 10.0.3.3 ping statistics ---

1 packet(s) transmitted

0 packet(s) received

100.00% packet loss

发现R2与R3的Loopback0接口地址之间的通讯存在问题。

检查R2的路由表。

[R2]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

10.0.1.1/32 OSPF 10 1562 D 10.0.12.1 Serial1/0/0

10.0.2.2/32 Direct 0 0 D 127.0.0.1 LoopBack0

10.0.12.0/24 Direct 0 0 D 10.0.12.2 Serial1/0/0

10.0.12.1/32 Direct 0 0 D 10.0.12.1 Serial1/0/0

10.0.12.2/32 Direct 0 0 D 127.0.0.1 Serial1/0/0

10.0.12.255/32 Direct 0 0 D 127.0.0.1 Serial1/0/0

10.0.23.0/24 Direct 0 0 D 10.0.23.2 Serial2/0/0

10.0.23.2/32 Direct 0 0 D 127.0.0.1 Serial2/0/0

10.0.23.3/32 Direct 0 0 D 10.0.23.3 Serial2/0/0

10.0.23.255/32 Direct 0 0 D 127.0.0.1 Serial2/0/0

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

127.255.255.255/32Direct 0 0 D 127.0.0.1 InLoopBack0

255.255.255.255/32Direct 0 0 D 127.0.0.1 InLoopBack0

发现没有到达地址10.0.3.3的路由。

检查R3的路由表。

[R3]display ip routing-table

Route Flags: R - relay, D - download to fib

----------------------------------------------------------------------------

Routing Tables: Public

Destinations : 9 Routes : 9

Destination/Mask Proto Pre Cost Flags NextHop Interface

10.0.3.3/32 Direct 0 0 D 127.0.0.1 LoopBack0

10.0.23.0/24 Direct 0 0 D 10.0.23.3 Serial2/0/0

10.0.23.2/32 Direct 0 0 D 10.0.23.2 Serial2/0/0

10.0.23.3/32 Direct 0 0 D 127.0.0.1 Serial2/0/0

10.0.23.255/32 Direct 0 0 D 127.0.0.1 Serial2/0/0

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

127.255.255.255/32Direct 0 0 D 127.0.0.1 InLoopBack0

255.255.255.255/32Direct 0 0 D 127.0.0.1 InLoopBack0

也没有到达R2的Loopback0地址10.0.2.2的路由。

对于不同的AS，使用静态路由可以实现相邻路由器的Loopback接口地址之间的可达性。

在这里，我们需要在R2和R3上分别添加到对端Loopback接口连接网段的静态路由。

[R2]ip route-static 10.0.3.3 32 10.0.23.3

[R3]ip route-static 10.0.2.2 32 10.0.23.2

检查R2到R3之间的连通性。

[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=255 time=30 ms

--- 10.0.3.3 ping statistics ---

1 packet(s) transmitted

1 packet(s) received

0.00% packet loss

round-trip min/avg/max = 30/30/30 ms

检查R2的BGP对等体关系。

[R2]display bgp peer

BGP local router ID : 10.0.2.2

Local AS number : 64512

Total number of peers : 2 Peers in established state : 0

Peer V AS MsgRcvd MsgSent OutQ Up/Down State PrefRcv

10.0.1.1 4 64512 0 0 0 05:23:27 Active 0

10.0.3.3 4 64513 0 0 0 05:23:02 Active 0

R2和R3之间的状态由刚才的Idle状态转变为Active状态。

接下来考虑R1和R2之间的对等体关系，刚才在配置OSPF之后已经验证了R1的Loopback接口地址到R2的Loopback接口地址之间的连通性。

BGP是通过TCP 179端口进行通信的。首先检查路由器的179端口是否处于打开状态。

在R1和R2上分别检查TCP状态。

[R1]display tcp status

TCPCB Tid/Soid Local Add:port Foreign Add:port VPNID State

37a32f14 76 /1 0.0.0.0:80 0.0.0.0:0 23553 Listening

37a33b34 239/2 0.0.0.0:179 10.0.2.2:0 0 Listening

37a3321c 76 /3 0.0.0.0:443 0.0.0.0:0 23553 Listening

[R2]display tcp status

TCPCB Tid/Soid Local Add:port Foreign Add:port VPNID State

37a32f14 76 /1 0.0.0.0:80 0.0.0.0:0 23553 Listening

37a33b34 239/2 0.0.0.0:179 10.0.1.1:0 0 Listening

390888bc 239/4 0.0.0.0:179 10.0.3.3:0 0 Listening

37a3321c 76 /3 0.0.0.0:443 0.0.0.0:0 23553 Listening

可以看到，对等体之间对应地址的179端口均处于监听状态。显示BGP协议在单个路由器上工作正常。

然后通过**debug**命令在R1上观察是否收到R2发来的BGP数据包。

<R1>terminal monitor

<R1>terminal debugging

<R1>debugging tcp packet

Nov 16 2016 16:34:56.300.1+00:00 R1 SOCKET/7/TCP PACKET:

TCP debug packet information:

1479314096: Input: no port,

(src = 10.0.12.2:64316,dst = 10.0.1.1:179,VrfIndex = 0,seq = 4034991477,

ack = 0,datalen = 0,optlen = 4,flag = SYN ,window = 16384,ttl = 0,tos = 0,MSS = 0)

Nov 16 2016 16:34:56.300.2+00:00 R1 SOCKET/7/TCP PACKET:

TCP debug packet information:

1479314096: Output: task = (0), socketid = 0,

(src = 10.0.1.1:179,dst = 10.0.12.2:64316,VrfIndex = 0,seq = 0,

ack = 4034991478,datalen = 0,optlen = 0,flag = ACK RST ,window = 0,ttl = 255,tos = 0,MSS = 0)

<R1>undo debugging all

Info: All possible debugging has been turned off

从上面的输出中可以看到R2发来的目的端口号为179的数据包的源地址为10.0.12.2。查看拓扑后发现该地址为R2的Serial1/0/0的接口地址。

在建立对等体关系时，使用的是R2的Loopback接口地址，这就造成R1和R2之间的对等体关系建立不起来。所以我们需要在建立对等体关系时需使用**connect-interface**指定更新源地址。

同样的，R2和R3之间也存在这个问题。在这里，一并进行修改。

[R1]bgp 64512

[R1-bgp]peer 10.0.2.2 connect-interface LoopBack 0

[R1-bgp]quit

[R2]bgp 64512

[R2-bgp]peer 10.0.1.1 connect-interface LoopBack 0

[R2-bgp]peer 10.0.3.3 connect-interface LoopBack 0

[R2-bgp]quit

[R3]bgp 64513

[R3-bgp]peer 10.0.2.2 connect-interface LoopBack 0

[R3-bgp]quit

修改完成以后再次在R2上检查对等体关系。

[R2]display bgp peer

BGP local router ID : 10.0.2.2

Local AS number : 64512

Total number of peers : 2 Peers in established state : 1

Peer V AS MsgRcvd MsgSent OutQ Up/Down State PrefRcv

10.0.1.1 4 64512 16 17 0 00:14:18 Established 0

10.0.3.3 4 64513 0 0 0 00:14:35 Idle 0

看到R1与R2之间的状态已经是Established状态了。

在R3上使用**debug**命令测试是否收到BGP数据包，并检查数据包的内容。

<R3>terminal monitor

<R3>terminal debugging

<R3>debugging ip packet

Nov 16 2016 16:52:11.880.4+00:00 R3 IP/7/debug\_case:

Receiving, interface = Serial2/0/0, version = 4, headlen = 20, tos = 192,

pktlen = 40, pktid = 3446, offset = 0, ttl = 1, protocol = 6,

checksum = 37526, s = 10.0.2.2, d = 10.0.3.3

prompt: Out interface if is loopback0 and packet is going to IP Distribute.

<R3>undo debugging all

Info: All possible debugging has been turned off

注意到R3收到的BGP数据包TTL值为1。对于EBGP来说，路由器向对等体发送的数据包默认的TTL就是1。

在这个场景中，R2和R3之间使用Loopback地址建立对等体关系。从R2的Loopback地址到R3的Loopback地址有2跳。所以该数据包在还没有到达R2的Loopback地址之前就因为TTL超时被丢弃了。

为了解决这个问题，我们需要修改EBGP对等体之间发送的数据包的TTL值。

[R2]bgp 64512

[R2-bgp]peer 10.0.3.3 ebgp-max-hop 2

[R2-bgp]quit

[R3]bgp 64513

[R3-bgp]peer 10.0.2.2 ebgp-max-hop 2

[R3-bgp]quit

配置完成以后，在R2上重新检查对等体之间的关系。

[R2]display bgp peer

BGP local router ID : 10.0.2.2

Local AS number : 64512

Total number of peers : 2 Peers in established state : 1

Peer V AS MsgRcvd MsgSent OutQ Up/Down State PrefRcv

10.0.1.1 4 64512 3 4 0 00:01:34 Established 0

10.0.3.3 4 64513 0 1 0 00:00:44 Idle 0

R2和R3之间仍停留在Idle状态。

在R3上检查BGP的错误。

[R3]display bgp error

Error Type : Peer Error

Date/Time : 2016/11/16 17:01:48

Peer Address : 10.0.2.2

VRF Name : Public

Error Info : Incorrect remote AS

Error Type : Peer Error

Date/Time : 2016/11/16 17:03:06

Peer Address : 10.0.2.2

VRF Name : Public

Error Info : Incorrect remote AS

Error Type : Peer Error

Date/Time : 2016/11/16 17:03:38

Peer Address : 10.0.2.2

VRF Name : Public

Error Info : Incorrect remote AS

<R3>terminal debugging

<R3>debugging bgp packet

Nov 16 2016 17:10:02.860.2+00:00 R3 RM/6/RMDEBUG:

BGP.Public: Err/SubErr: 2/2 Errdata: 41040000fc00

Identified in OPEN MSG from 10.0.2.2.

Nov 16 2016 17:10:02.860.3+00:00 R3 RM/6/RMDEBUG:

Nov 16 2016 17:10:02.860.4+00:00 R3 RM/6/RMDEBUG:

BGP.Public: Err/SubErr: 2/2 Errdata: 41040000fc00

Identified in OPEN MSG from 10.0.2.2.

出现的是AS号错误的消息。

使用**debug**命令来诊断该错误。

从上面的输出中我们可以看到，错误号/子错误号是2。翻阅文档可知，该错误就是AS号不匹配。接下来我们在R3上修改对等体的AS号。

[R3]bgp 64513

[R3-bgp]undo peer 10.0.2.2

[R3-bgp]peer 10.0.2.2 as-number 64512

[R3-bgp]peer 10.0.2.2 ebgp-max-hop 2

[R3-bgp]peer 10.0.2.2 connect-interface LoopBack0

[R3-bgp]quit

这时再检查R2和R3之间的对等体关系。

[R2]display bgp peer

BGP local router ID : 10.0.2.2

Local AS number : 64512

Total number of peers : 2 Peers in established state : 2

Peer V AS MsgRcvd MsgSent OutQ Up/Down State PrefRcv

10.0.1.1 4 64512 81 82 0 01:19:18 Established 0

10.0.3.3 4 64513 3 4 0 00:01:12 Established 0

1. BGP安全

BGP通常用在骨干网上，其安全性显得尤为重要。一旦BGP路由器被攻击，将会造成大面积网络瘫痪。

通常为了防止非法恶意用户冒充合法路由器与BGP路由器建立对等体关系，在BGP对等体会话之间会设置MD5认证。

R1和R2之间开启MD5的认证。首先设置一个错误的密码。在R1上设置密码为huawei，在R2上设置密码为123，观察对等体关系的变化情况。

[R1]bgp 64512

[R1-bgp]peer 10.0.2.2 password simple huawei

[R1-bgp]quit

[R2]bgp 64512

[R2-bgp]peer 10.0.1.1 password simple 123

[R2-bgp]quit

在R1上重置BGP对等体关系，这时可以观察到R1与R2的对等体关系已停留在Connect和Active状态。无法进入Established状态。

<R1>reset bgp 10.0.2.2

[R1]display bgp peer

BGP local router ID : 10.0.1.1

Local AS number : 64512

Total number of peers : 1 Peers in established state : 0

Peer V AS MsgRcvd MsgSent OutQ Up/Down State PrefRcv

10.0.2.2 4 64512 0 0 0 00:03:39 Connect 0

我们把R2的密码改成huawei。

[R2]bgp 64512

[R2-bgp]undo peer 10.0.1.1 password

[R2-bgp]peer 10.0.1.1 password simple huawei

[R2-bgp]quit

等待约半分钟，再次查看对等体关系。

[R2]display bgp peer

BGP local router ID : 10.0.2.2

Local AS number : 64512

Total number of peers : 2 Peers in established state : 2

Peer V AS MsgRcvd MsgSent OutQ Up/Down State PrefRcv

10.0.1.1 4 64512 2 2 0 00:00:34 Established 0

10.0.3.3 4 64513 166 167 0 02:44:05 Established 0

这时，R1和R2之间的对等体关系已经到达了Established状态。

在这个场景中AS 64512的管理员不希望AS64513中的路由器看自己的真实AS号。

**fake-as**的功能就能达到这个目的，该命令可以用来为本端对等体指定一个伪AS号。

我们在R2上针对R3配置这条命令，伪装以后的AS号为100。

同时，也要修改R3配置的BGP对等体R2的AS号。

[R2]bgp 64512

[R2-bgp]peer 10.0.3.3 fake-as 100

[R2-bgp]quit

[R3]bgp 64513

[R3-bgp]undo peer 10.0.2.2

[R3-bgp]peer 10.0.2.2 as-number 100

[R3-bgp]peer 10.0.2.2 ebgp-max-hop 2

[R3-bgp]peer 10.0.2.2 connect-interface LoopBack0

[R3-bgp]quit

在R3上检查对等体，发现R2的AS号已经变成了100。

[R3]display bgp peer

BGP local router ID : 10.0.3.3

Local AS number : 64513

Total number of peers : 1 Peers in established state : 1

Peer V AS MsgRcvd MsgSent OutQ Up/Down State PrefRcv

10.0.2.2 4 100 2 2 0 00:00:28 Established 0

在R2上发布自己的Loopback 0接口所在网段，观察在R3上学习到的BGP路由的AS-Path属性。

[R2]bgp 64512

[R2-bgp]network 10.0.2.2 32

[R2-bgp]quit

[R3]display bgp routing-table

BGP Local router ID is 10.0.3.3

Status codes: \* - valid, > - best, d - damped,

h - history, i - internal, s - suppressed, S - Stale

Origin : i - IGP, e - EGP, ? - incomplete

Total Number of Routes: 1

Network NextHop MED LocPrf PrefVal Path/Ogn

10.0.2.2/32 10.0.2.2 0 0 100i

可以看到在R3上学习到的路由10.0.2.2/32的AS-Path是100，即R3认为该路由是在AS100始发的，这样就达到了隐藏AS 64512的目的。

BGP还提供了一种安全特性：GTSM。该特性通过检测IP报文头中的TTL值是否在一个预先定义好的范围内来对路由器进行保护。也就是说，若收到的BGP报文的TTL值超出了预先设定的值的范围以后，就丢弃该报文。注意GTSM和ebgp-max-hop功能均会影响到发送出去的BGP报文的TTL值，存在冲突。只能对同一对等体或对等体组使能两种功能中的一种。

在这个场景中，我们对R2和R3之间的链路开启该特性，观察BGP报文的交互。首先在R2的系统视图下设置违背GTSM规则的缺省动作，在这里我们选择**drop**，即不符合要求的BGP数据包将会被丢弃。

[R2]gtsm default-action drop

然后在BGP视图下针对R3开启GTSM特性。在配置之前需先要删除**ebgp-max-hop**的配置，注意这里从R2和R3是直连的，所以这里的**valid-ttl-hops**参数填1。

[R2]bgp 64512

[R2-bgp]undo peer 10.0.3.3 ebgp-max-hop

[R2-bgp]peer 10.0.3.3 valid-ttl-hops 1

[R2-bgp]peer 10.0.1.1 valid-ttl-hops 1

[R2-bgp]quit

在R1和R3上进行相同的操作。

[R1]gtsm default-action drop

[R1]bgp 64512

[R1-bgp]peer 10.0.2.2 valid-ttl-hops 1

[R1-bgp]quit

[R3]gtsm default-action drop

[R3]bgp 64513

[R3-bgp]undo peer 10.0.2.2 ebgp-max-hop

[R3-bgp]peer 10.0.2.2 valid-ttl-hops 1

[R3-bgp]quit

检查R2和R3之间的对等体关系。

[R3]dis bgp peer

BGP local router ID : 10.0.3.3

Local AS number : 64513

Total number of peers : 1 Peers in established state : 1

Peer V AS MsgRcvd MsgSent OutQ Up/Down State PrefRcv

10.0.2.2 4 100 3 2 0 00:00:06 Established 1

在R3上观察使用了该命令以后BGP报文TTL值的变化。

<R3>terminal monitor

<R3>terminal debugging

<R3>debugging ip packet

Nov 16 2016 17:24:45.340.1+00:00 R3 IP/7/debug\_case:

Receiving, interface = S2/0/0, version = 4, headlen = 20, tos = 192,

pktlen = 59, pktid = 4015, offset = 0, ttl = 255, protocol = 6,

checksum = 37449, s = 10.0.2.2, d = 10.0.3.3

prompt: Receiving IP packet from S2/0/0

45 c0 00 3b 0f af 00 00 ff 06 92 49 0a 00 02 02

0a 00 03 03

Nov 16 2016 17:24:45.340.2+00:00 R3 IP/7/debug\_case:

Receiving, interface = Serial2/0/0, version = 4, headlen = 20, tos = 192,

pktlen = 59, pktid = 4015, offset = 0, ttl = 255, protocol = 6,

checksum = 37449, s = 10.0.2.2, d = 10.0.3.3

prompt: IP Process By Board Begin!

45 c0 00 3b 0f af 00 00 ff 06 92 49 0a 00 02 02

0a 00 03 03

<R3>undo debugging all

Info: All possible debugging has been turned off

这时看到R3接收到的从R2发来的数据包的TTL值为255，而不是EBGP的默认值1。为了确认GTSM会丢弃TTL不合规定的BGP数据包，我们首先在R3上打开GTSM日志记录功能，当有数据包被GTSM丢弃时就记录相应信息。

[R3]gtsm log drop-packet all

然后在R2上配置**ebgp-max-hop**命令，使R2发给R3的BGP数据包的TTL值小于254。

[R2]bgp 64512

[R2-bgp]undo peer 10.0.3.3 valid-ttl-hops

[R2-bgp]peer 10.0.3.3 ebgp-max-hop 253

[R2-bgp]quit

等待一段时间以后，可以看到R2和R3之间的对等体关系进入了IDLE状态。现在R3上查看GTSM统计信息可以发现，已经有数据包被GTSM丢弃了。

[R3]

Nov 16 2016 17:30:44+00:00 R3 %%01BGP/3/STATE\_CHG\_UPDOWN(l)[6]:The status of the peer 10.0.2.2 changed from ESTABLISHED to IDLE. (InstanceName=Public, StateChangeReason=Hold Timer Expired)

[R3]display gtsm statistics all

GTSM Statistics Table

----------------------------------------------------------------

SlotId Protocol Total Counters Drop Counters Pass Counters

----------------------------------------------------------------

0 BGP 29 15 14

0 BGPv6 0 0 0

0 OSPF 0 0 0

0 LDP 0 0 0

0 OSPFv3 0 0 0

0 RIP 0 0 0

----------------------------------------------------------------

把R2的配置修改回来，间隔一段时间以后再观察是否有数据包被丢弃掉。

[R2]bgp 64512

[R2-bgp]undo peer 10.0.3.3 ebgp-max-hop

[R2-bgp]peer 10.0.3.3 valid-ttl-hops 1

[R2-bgp]quit

[R3]display gtsm statistics all

GTSM Statistics Table

----------------------------------------------------------------

SlotId Protocol Total Counters Drop Counters Pass Counters

----------------------------------------------------------------

0 BGP 69 37 32

0 BGPv6 0 0 0

0 OSPF 0 0 0

0 LDP 0 0 0

0 OSPFv3 0 0 0

0 RIP 0 0 0

----------------------------------------------------------------

这时我们看到已经没有新的数据包被丢弃掉了。

## **附加实验: 思考并验证**

GTSM主要用于防止哪种类型的攻击？

在联盟环境中是否可以使用fake-as？

## **最终设备配置**

<R1>**display current-configuration**

[V200R007C00SPC600]

#

sysname R1

#

router id 10.0.1.1

#

gtsm default-action drop

#

interface Serial1/0/0

link-protocol ppp

ip address 10.0.12.1 255.255.255.0

#

interface LoopBack0

ip address 10.0.1.1 255.255.255.255

#

bgp 64512

peer 10.0.2.2 as-number 64512

peer 10.0.2.2 connect-interface LoopBack0

peer 10.0.2.2 password simple huawei

peer 10.0.2.2 valid-ttl-hops 1

#

ipv4-family unicast

undo synchronization

peer 10.0.2.2 enable

#

ospf 1 router-id 10.0.1.1

area 0.0.0.0

network 10.0.12.1 0.0.0.0

network 10.0.1.1 0.0.0.0

#

return

<R2>**display current-configuration**

[V200R007C00SPC600]

#

sysname R2

#

router id 10.0.2.2

#

gtsm default-action drop

#

acl number 2001

rule 5 permit source 10.0.2.2 0

#

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 10.0.2.2 255.255.255.255

#

bgp 64512

peer 10.0.1.1 as-number 64512

peer 10.0.1.1 connect-interface LoopBack0

peer 10.0.1.1 password simple huawei

peer 10.0.1.1 valid-ttl-hops 1

peer 10.0.3.3 as-number 64513

peer 10.0.3.3 connect-interface LoopBack0

peer 10.0.3.3 fake-as 100

peer 10.0.3.3 valid-ttl-hops 1

#

ipv4-family unicast

undo synchronization

network 10.0.2.2 255.255.255.255

peer 10.0.1.1 enable

peer 10.0.1.1 next-hop-local

peer 10.0.3.3 enable

#

ospf 1 router-id 10.0.2.2

area 0.0.0.0

network 10.0.12.2 0.0.0.0

network 10.0.2.2 0.0.0.0

#

route-policy change\_origin deny node 10

if-match acl 2001

apply origin egp 100

#

ip route-static 10.0.3.3 255.255.255.255 10.0.23.3

#

return

<R3>**display current-configuration**

[V200R007C00SPC600]

#

sysname R3

#

router id 10.0.3.3

#

gtsm default-action drop

gtsm log drop-packet all

#

interface Serial2/0/0

link-protocol ppp

ip address 10.0.23.3 255.255.255.0

#

interface LoopBack0

ip address 10.0.3.3 255.255.255.255

#

bgp 64513

peer 10.0.2.2 as-number 100

peer 10.0.2.2 connect-interface LoopBack0

peer 10.0.2.2 valid-ttl-hops 1

#

ipv4-family unicast

undo synchronization

peer 10.0.2.2 enable

#

ip route-static 10.0.2.2 255.255.255.255 10.0.23.2

#

return

第四章 路由控制

实验 4-1 路由引入与路由控制

学习目的

* 掌握OSPF与ISIS相互路由引入的配置方法
* 掌握通过地址前缀列表过滤路由信息的配置方法
* 掌握通过Route-policy过滤路由信息的配置方法

## **拓扑图**

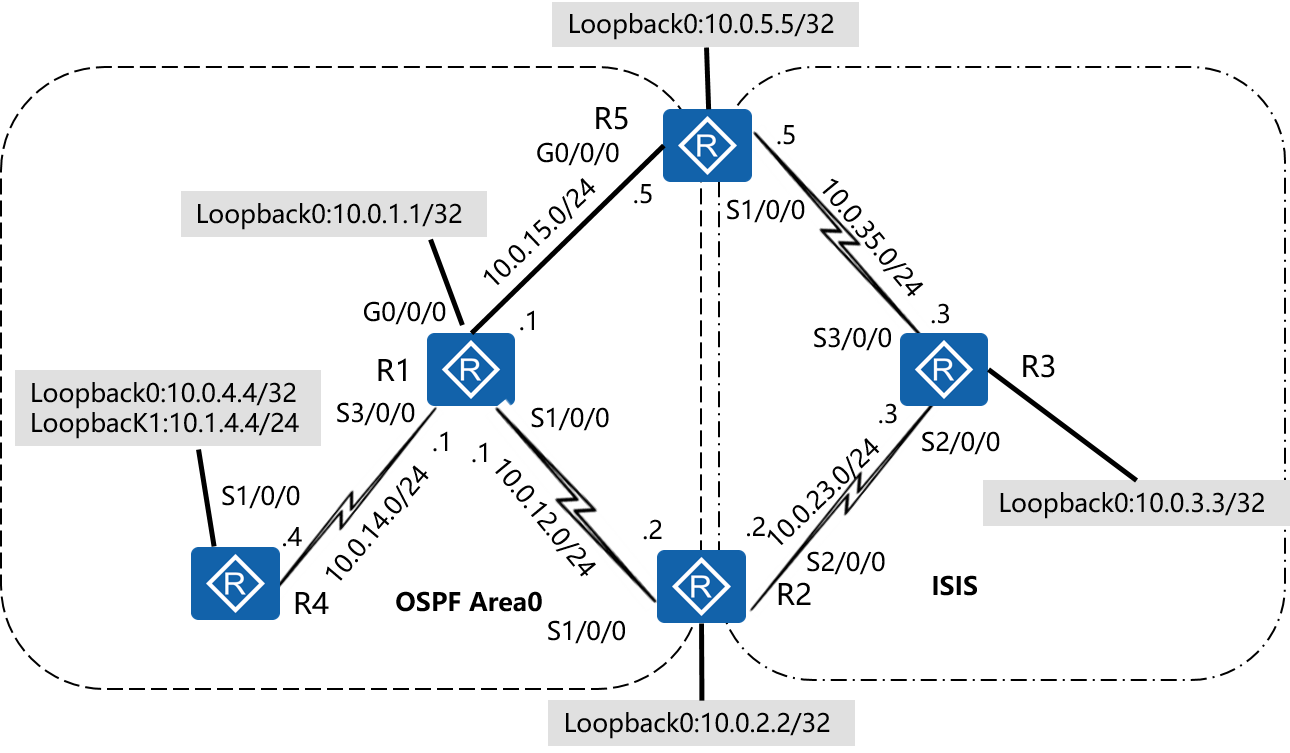


图4-1 路由引入与路由控制

## **场景**

你是你们公司的网络管理员。公司网络中有两部分路由区域，一部分运行OSPF,另外一部分运行RIP。为了实现网络互通，你需要配置路由相互引入。在典型的双点双向路由引入中，会出现一些问题。为了解决这些问题，避免可能出现的路由环路和次优路径的产生，现在你需要使用到前缀列表和路由策略对路由进行控制。

## **学习任务**

1. 基础配置与IP编址

给所有路由器配置物理接口以及Loopback接口的IP地址和掩码。注意各Loopback 0接口均使用32位掩码。

<R1>system-view

Enter system view, return user view with Ctrl+Z.

[R1]interface Serial 1/0/0

[R1-Serial1/0/0]ip address 10.0.12.1 255.255.255.0

[R1-Serial1/0/0]interface GigabitEthernet 0/0/0

[R1-GigabitEthernet0/0/0]ip address 10.0.15.1 255.255.255.0

[R1-GigabitEthernet0/0/0]interface Serial 3/0/0

[R1-Serial3/0/0]ip address 10.0.14.1 255.255.255.0

[R1-Serial3/0/0]interface LoopBack 0

[R1-LoopBack0]ip address 10.0.1.1 255.255.255.255

<R2>system-view

Enter system view, return user view with Ctrl+Z.

[R2]interface Serial 1/0/0

[R2-Serial1/0/0]ip address 10.0.12.2 255.255.255.0

[R2-Serial1/0/0]interface Serial 2/0/0

[R2-Serial2/0/0]ip address 10.0.23.2 255.255.255.0

[R2-Serial2/0/0]interface LoopBack 0

[R2-LoopBack0]ip add 10.0.2.2 255.255.255.255

<R3>system-view

Enter system view, return user view with Ctrl+Z.

[R3]interface Serial 2/0/0

[R3-Serial2/0/0]ip address 10.0.23.3 255.255.255.0

[R3-Serial2/0/0]interface Serial 3/0/0

[R3-Serial3/0/0]ip address 10.0.35.3 255.255.255.0

[R3-Serial3/0/0]interface LoopBack 0

[R3-LoopBack0]ip address 10.0.3.3 255.255.255.255

<R4>system-view

Enter system view, return user view with Ctrl+Z.

[R4]interface Serial 1/0/0

[R4-Serial1/0/0]ip address 10.0.14.4 255.255.255.0

[R4-Serial1/0/0]interface LoopBack 0

[R4-LoopBack0]ip address 10.0.4.4 255.255.255.255

<R5>system-view

Enter system view, return user view with Ctrl+Z.

[R5]interface Serial 1/0/0

[R5-Serial1/0/0]ip address 10.0.35.5 255.255.255.0

[R5-Serial1/0/0]interface GigabitEthernet 0/0/0

[R5-GigabitEthernet0/0/0]ip address 10.0.15.5 255.255.255.0

[R5-GigabitEthernet0/0/0]interface LoopBack 0

[R5-LoopBack0]ip address 10.0.5.5 255.255.255.255

配置完成后，测试直连链路的连通性。

[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=38 ms

--- 10.0.12.2 ping statistics ---

1 packet(s) transmitted

1 packet(s) received

0.00% packet loss

round-trip min/avg/max = 38/38/38 ms

[R1]ping -c 1 10.0.15.5

PING 10.0.15.5: 56 data bytes, press CTRL\_C to break

Reply from 10.0.15.5: bytes=56 Sequence=1 ttl=255 time=12 ms

--- 10.0.15.5 ping statistics ---

1 packet(s) transmitted

1 packet(s) received

0.00% packet loss

round-trip min/avg/max = 12/12/12 ms

[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=33 ms

--- 10.0.14.4 ping statistics ---

1 packet(s) transmitted

1 packet(s) received

0.00% packet loss

round-trip min/avg/max = 33/33/33 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=34 ms

--- 10.0.23.3 ping statistics ---

1 packet(s) transmitted

1 packet(s) received

0.00% packet loss

round-trip min/avg/max = 34/34/34 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=39 ms

--- 10.0.35.5 ping statistics ---

1 packet(s) transmitted

1 packet(s) received

0.00% packet loss

round-trip min/avg/max = 39/39/39 ms

1. 配置IGP

在R1，R2，R4，R5上运行OSPF，所有设备属于区域0。

配置R1的S1/0/0，S3/0/0，G0/0/0和Loopback0连接的网段运行OSPF，

[R1]ospf 1

[R1-ospf-1]area 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 10.0.15.1 0.0.0.0

[R1-ospf-1-area-0.0.0.0]network 10.0.14.1 0.0.0.0

[R1-ospf-1-area-0.0.0.0]network 10.0.1.1 0.0.0.0

配置R2的S1/0/0连接的网段运行OSPF。

[R2]ospf 1

[R2-ospf-1]area 0

[R2-ospf-1-area-0.0.0.0]network 10.0.12.2 0.0.0.0

配置R4的S1/0/0和Loopback 0连接的网段运行OSPF。

[R4]ospf 1

[R4-ospf-1]area 0

[R4-ospf-1-area-0.0.0.0]network 10.0.14.4 0.0.0.0

[R4-ospf-1-area-0.0.0.0]network 10.0.4.4 0.0.0.0

配置R5的G0/0/0连接的网段运行OSPF。

[R5]ospf 1

[R5-ospf-1]area 0

[R5-ospf-1-area-0.0.0.0]network 10.0.15.5 0.0.0.0

检查是否学习到其他设备上的Loopback0接口连接网段的路由。

[R1]display ip routing-table

Route Flags: R - relay, D - download to fib

----------------------------------------------------------------------------

Routing Tables: Public

Destinations : 17 Routes : 17

Destination/Mask Proto Pre Cost Flags NextHop Interface

10.0.1.1/32 Direct 0 0 D 127.0.0.1 LoopBack0

10.0.4.4/32 OSPF 10 1562 D 10.0.14.4 Serial3/0/0

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 Serial1/0/0

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 Serial1/0/0

10.0.14.0/24 Direct 0 0 D 10.0.14.1 Serial3/0/0

10.0.14.1/32 Direct 0 0 D 127.0.0.1 Serial3/0/0

10.0.14.4/32 Direct 0 0 D 10.0.14.4 Serial3/0/0

10.0.14.255/32 Direct 0 0 D 127.0.0.1 Serial3/0/0

10.0.15.0/24 Direct 0 0 D 10.0.15.1 GigabitEthernet0/0/0

10.0.15.1/32 Direct 0 0 D 127.0.0.1 GigabitEthernet0/0/0

10.0.15.255/32 Direct 0 0 D 127.0.0.1 GigabitEthernet0/0/0

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

127.255.255.255/32Direct 0 0 D 127.0.0.1 InLoopBack0

255.255.255.255/32Direct 0 0 D 127.0.0.1 InLoopBack0

[R2]display ip routing-table

Route Flags: R - relay, D - download to fib

----------------------------------------------------------------------------

Routing Tables: Public

Destinations : 17 Routes : 17

Destination/Mask Proto Pre Cost Flags NextHop Interface

10.0.1.1/32 OSPF 10 1562 D 10.0.12.1 Serial1/0/0

10.0.2.2/32 Direct 0 0 D 127.0.0.1 LoopBack0

10.0.4.4/32 OSPF 10 3124 D 10.0.12.1 Serial1/0/0

10.0.12.0/24 Direct 0 0 D 10.0.12.2 Serial1/0/0

10.0.12.1/32 Direct 0 0 D 10.0.12.1 Serial1/0/0

10.0.12.2/32 Direct 0 0 D 127.0.0.1 Serial1/0/0

10.0.12.255/32 Direct 0 0 D 127.0.0.1 Serial1/0/0

10.0.14.0/24 OSPF 10 3124 D 10.0.12.1 Serial1/0/0

10.0.15.0/24 OSPF 10 1563 D 10.0.12.1 Serial1/0/0

10.0.23.0/24 Direct 0 0 D 10.0.23.2 Serial2/0/0

10.0.23.2/32 Direct 0 0 D 127.0.0.1 Serial2/0/0

10.0.23.3/32 Direct 0 0 D 10.0.23.3 Serial2/0/0

10.0.23.255/32 Direct 0 0 D 127.0.0.1 Serial2/0/0

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

127.255.255.255/32Direct 0 0 D 127.0.0.1 InLoopBack0

255.255.255.255/32Direct 0 0 D 127.0.0.1 InLoopBack0

[R4]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 1562 D 10.0.14.1 Serial1/0/0

10.0.4.4/32 Direct 0 0 D 127.0.0.1 LoopBack0

10.0.12.0/24 OSPF 10 3124 D 10.0.14.1 Serial1/0/0

10.0.14.0/24 Direct 0 0 D 10.0.14.4 Serial1/0/0

10.0.14.1/32 Direct 0 0 D 10.0.14.1 Serial1/0/0

10.0.14.4/32 Direct 0 0 D 127.0.0.1 Serial1/0/0

10.0.14.255/32 Direct 0 0 D 127.0.0.1 Serial1/0/0

10.0.15.0/24 OSPF 10 1563 D 10.0.14.1 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

127.255.255.255/32Direct 0 0 D 127.0.0.1 InLoopBack0

255.255.255.255/32Direct 0 0 D 127.0.0.1 InLoopBack0

[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

10.0.1.1/32 OSPF 10 1 D 10.0.15.1 GigabitEthernet0/0/0

10.0.4.4/32 OSPF 10 1563 D 10.0.15.1 LoopBack0

10.0.5.5/32 Direct 0 0 D 127.0.0.1 GigabitEthernet0/0/0

10.0.12.0/24 OSPF 10 1563 D 10.0.15.1 GigabitEthernet0/0/0

10.0.14.0/24 OSPF 10 1563 D 10.0.15.1 GigabitEthernet0/0/0

10.0.15.0/24 Direct 0 0 D 10.0.15.5 GigabitEthernet0/0/0

10.0.15.5/32 Direct 0 0 D 127.0.0.1 GigabitEthernet0/0/0

10.0.15.255/32 Direct 0 0 D 127.0.0.1 GigabitEthernet0/0/0

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 Serial1/0/0

10.0.35.255/32 Direct 0 0 D 127.0.0.1 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

127.255.255.255/32Direct 0 0 D 127.0.0.1 InLoopBack0

255.255.255.255/32Direct 0 0 D 127.0.0.1 InLoopBack0

在R2，R3，R5上配置RIP。

R2的S2/0/0和Loopback0连接的网段运行ISIS，

[R2]isis 1

[R2-isis-1]network-entity 49.0001.0000.0000.0002.00

[R2-isis-1]is-level level-2

[R2-isis-1]interface serial2/0/0

[R2-Serial2/0/0]isis enable 1

[R2]interface loopback0

[R2-LoopBack0]isis enable 1

R3的S2/0/0，S3/0/0和Loopback0连接的网段运行ISIS，

[R3]rip

[R3-rip-1]version 2

[R3-rip-1]network 10.0.0.0

[R3-rip-1]quit

[R3]isis 1

[R3-isis-1]network-entity 49.0001.0000.0000.0003.00

[R3-isis-1]is-level level-2

[R3-isis-1]interface serial2/0/0

[R3-Serial2/0/0]isis enable 1

[R3-Serial2/0/0]interface serial3/0/0

[R3-Serial3/0/0]isis enable 1

[R3-Serial3/0/0]interface loopback0

[R3-LoopBack0]isis enable 1

R5的S1/0/0和Loopback0连接的网段运行ISIS，

[R5]isis 1

[R5-isis-1]network-entity 49.0001.0000.0000.0005.00

[R5-isis-1]is-level level-2

[R5-isis-1]interface serial1/0/0

[R5-Serial1/0/0]isis enable 1

[R5-Serial1/0/0]interface loopback 0

[R5-LoopBack0]isis enable 1

检查是否学习到其他设备上的Loopback0地址。

[R2]display ip routing-table

Route Flags: R - relay, D - download to fib

------------------------------------------------------------------------------

Routing Tables: Public

Destinations : 20 Routes : 20

Destination/Mask Proto Pre Cost Flags NextHop Interface

10.0.1.1/32 OSPF 10 48 D 10.0.12.1 Serial1/0/0

10.0.2.2/32 Direct 0 0 D 127.0.0.1 LoopBack0

10.0.3.3/32 ISIS-L2 15 10 D 10.0.23.3 Serial2/0/0

10.0.4.4/32 OSPF 10 96 D 10.0.12.1 Serial1/0/0

10.0.5.5/32 ISIS-L2 15 20 D 10.0.23.3 Serial2/0/0

10.0.12.0/24 Direct 0 0 D 10.0.12.2 Serial1/0/0

10.0.12.1/32 Direct 0 0 D 10.0.12.1 Serial1/0/0

10.0.12.2/32 Direct 0 0 D 127.0.0.1 Serial1/0/0

10.0.12.255/32 Direct 0 0 D 127.0.0.1 Serial1/0/0

10.0.14.0/24 OSPF 10 96 D 10.0.12.1 Serial1/0/0

10.0.15.0/24 OSPF 10 49 D 10.0.12.1 Serial1/0/0

10.0.23.0/24 Direct 0 0 D 10.0.23.2 Serial2/0/0

10.0.23.2/32 Direct 0 0 D 127.0.0.1 Serial2/0/0

10.0.23.3/32 Direct 0 0 D 10.0.23.3 Serial2/0/0

10.0.23.255/32 Direct 0 0 D 127.0.0.1 Serial2/0/0

10.0.35.0/24 ISIS-L2 15 20 D 10.0.23.3 Serial2/0/0

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

[R3]dis ip routing-table

Route Flags: R - relay, D - download to fib

------------------------------------------------------------------------------

Routing Tables: Public

Destinations : 15 Routes : 15

Destination/Mask Proto Pre Cost Flags NextHop Interface

10.0.2.2/32 ISIS-L2 15 10 D 10.0.23.2 Serial2/0/0

10.0.3.3/32 Direct 0 0 D 127.0.0.1 LoopBack0

10.0.5.5/32 ISIS-L2 15 10 D 10.0.35.5 Serial3/0/0

10.0.23.0/24 Direct 0 0 D 10.0.23.3 Serial2/0/0

10.0.23.2/32 Direct 0 0 D 10.0.23.2 Serial2/0/0

10.0.23.3/32 Direct 0 0 D 127.0.0.1 Serial2/0/0

10.0.23.255/32 Direct 0 0 D 127.0.0.1 Serial2/0/0

10.0.35.0/24 Direct 0 0 D 10.0.35.3 Serial3/0/0

10.0.35.3/32 Direct 0 0 D 127.0.0.1 Serial3/0/0

10.0.35.5/32 Direct 0 0 D 10.0.35.5 Serial3/0/0

10.0.35.255/32 Direct 0 0 D 127.0.0.1 Serial3/0/0

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

[R5]display ip routing-table

Route Flags: R - relay, D - download to fib

------------------------------------------------------------------------------

Routing Tables: Public

Destinations : 19 Routes : 19

Destination/Mask Proto Pre Cost Flags NextHop Interface

10.0.1.1/32 OSPF 10 1 D 10.0.15.1 GigabitEthernet0/0/0

10.0.2.2/32 ISIS-L2 15 20 D 10.0.35.3 Serial1/0/0

10.0.3.3/32 ISIS-L2 15 10 D 10.0.35.3 Serial1/0/0

10.0.4.4/32 OSPF 10 49 D 10.0.15.1 GigabitEthernet0/0/0

10.0.5.5/32 Direct 0 0 D 127.0.0.1 LoopBack0

10.0.12.0/24 OSPF 0 49 D 10.0.15.1 GigabitEthernet0/0/0

10.0.14.0/24 OSPF 10 49 D 10.0.15.1 GigabitEthernet0/0/0

10.0.15.0/24 Direct 0 0 D 10.0.15.5 GigabitEthernet0/0/0

10.0.15.5/32 Direct 0 0 D 127.0.0.1 GigabitEthernet0/0/0

10.0.15.255/32 Direct 0 0 D 127.0.0.1 GigabitEthernet0/0/0

10.0.23.0/24 ISIS-L2 15 20 D 10.0.35.3 Serial1/0/0

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 Serial1/0/0

10.0.35.255/32 Direct 0 0 D 127.0.0.1 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

1. 配置前缀列表过滤路由信息

在R1上创建静态路由1.1.1.1/32，1.1.1.0/24，1.1.1.0/25，1.1.0.0/16，1.0.0.0/8分别指向NULL 0接口。并使用**import-route static**命令将这些路由引入OSPF中。

[R1]ip route-static 1.1.1.1 255.255.255.255 NULL 0

[R1]ip route-static 1.1.1.0 255.255.255.0 NULL 0

[R1]ip route-static 1.1.1.0 255.255.255.128 NULL 0

[R1]ip route-static 1.1.0.0 255.255.0.0 NULL 0

[R1]ip route-static 1.0.0.0 255.0.0.0 NULL 0

[R1]ospf 1

[R1-ospf-1]import-route static

在R4上检查是否接收到R1上添加的这几条静态路由。

[R4]display ip routing-table

Route Flags: R - relay, D - download to fib

----------------------------------------------------------------------------

Routing Tables: Public

Destinations : 17 Routes : 17

Destination/Mask Proto Pre Cost Flags NextHop Interface

1.0.0.0/8 O\_ASE 150 1 D 10.0.14.1 Serial1/0/0

1.1.0.0/16 O\_ASE 150 1 D 10.0.14.1 Serial1/0/0

1.1.1.0/24 O\_ASE 150 1 D 10.0.14.1 Serial1/0/0

1.1.1.0/25 O\_ASE 150 1 D 10.0.14.1 Serial1/0/0

1.1.1.1/32 O\_ASE 150 1 D 10.0.14.1 Serial1/0/0

10.0.1.1/32 OSPF 10 1562 D 10.0.14.1 Serial1/0/0

10.0.4.4/32 Direct 0 0 D 127.0.0.1 LoopBack0

10.0.12.0/24 OSPF 10 3124 D 10.0.14.1 Serial1/0/0

10.0.14.0/24 Direct 0 0 D 10.0.14.4 Serial1/0/0

10.0.14.1/32 Direct 0 0 D 10.0.14.1 Serial1/0/0

10.0.14.4/32 Direct 0 0 D 127.0.0.1 Serial1/0/0

10.0.14.255/32 Direct 0 0 D 127.0.0.1 Serial1/0/0

10.0.15.0/24 OSPF 10 1563 D 10.0.14.1 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

在R1上配置前缀列表pref\_r1，匹配路由1.1.1.0/24。

[R1]ip ip-prefix pref\_r1 index 10 permit 1.1.1.0 24 greater-equal 24 less-equal 24

创建路由策略policy\_r1，调用前缀列表pref\_r1，控制R1上引入的静态路由信息。

[R1]route-policy policy\_r1 permit node 10

[R1-route-policy]if-match ip-prefix pref\_r1

[R1-route-policy]quit

[R1]ospf

[R1-ospf-1]import-route static route-policy policy\_r1

[R1-ospf-1]quit

在R4上查看路由表。

[R4]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

1.1.1.0/24 O\_ASE 150 1 D 10.0.14.1 Serial1/0/0

10.0.1.1/32 OSPF 10 1562 D 10.0.14.1 Serial1/0/0

10.0.4.4/32 Direct 0 0 D 127.0.0.1 LoopBack0

10.0.12.0/24 OSPF 10 3124 D 10.0.14.1 Serial1/0/0

10.0.14.0/24 Direct 0 0 D 10.0.14.4 Serial1/0/0

10.0.14.1/32 Direct 0 0 D 10.0.14.1 Serial1/0/0

10.0.14.4/32 Direct 0 0 D 127.0.0.1 Serial1/0/0

10.0.14.255/32 Direct 0 0 D 127.0.0.1 Serial1/0/0

10.0.15.0/24 OSPF 10 1563 D 10.0.14.1 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

1. 使用Route-policy过滤路由信息避免路由环路

在R4上创建Loopback1，地址为10.1.4.4/24，使用**import-route direct**命令引入OSPF中。

[R4]interface LoopBack 1

[R4-LoopBack1]ip address 10.1.4.4 255.255.255.0

[R4-LoopBack1]quit

[R4]ospf 1

[R4-ospf-1]import-route direct

[R4-ospf-1]quit

在R2上将OSPF引入到ISIS 中，在R5上将ISIS引入到OSPF中。

[R2]rip

[R2-rip-1]import-route ospf

[R2]isis 1

**[R2-isis-1]import-route ospf**

[R2-rip-1]quit

[R5]ospf 1

[R5-ospf-1]import-route rip

[R5-rip-1]quit

在R1上测试到10.1.4.4的连通性。

[R1]ping 10.1.4.4

PING 10.1.4.4: 56 data bytes, press CTRL\_C to break

Request time out

Request time out

Request time out

Request time out

Request time out

--- 10.1.4.4 ping statistics ---

5 packet(s) transmitted

0 packet(s) received

100.00% packet loss

发现不通，查看R1路由表。

[R1]display ip routing-table

Route Flags: R - relay, D - download to fib

----------------------------------------------------------------------------

Routing Tables: Public

Destinations : 28 Routes : 28

Destination/Mask Proto Pre Cost Flags NextHop Interface

1.0.0.0/8 Static 60 0 D 0.0.0.0 NULL0

1.1.0.0/16 Static 60 0 D 0.0.0.0 NULL0

1.1.1.0/24 Static 60 0 D 0.0.0.0 NULL0

1.1.1.0/25 Static 60 0 D 0.0.0.0 NULL0

1.1.1.1/32 Static 60 0 D 0.0.0.0 NULL0

10.0.1.1/32 Direct 0 0 D 127.0.0.1 LoopBack0

10.0.2.2/32 O\_ASE 150 1 D 10.0.15.5 GigabitEthernet0/0/0

10.0.3.3/32 O\_ASE 150 1 D 10.0.15.5 GigabitEthernet0/0/0

10.0.4.4/32 OSPF 10 1562 D 10.0.14.4 Serial3/0/0

10.0.5.5/32 O\_ASE 150 1 D 10.0.15.5 GigabitEthernet0/0/0

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 Serial1/0/0

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 Serial1/0/0

10.0.14.0/24 Direct 0 0 D 10.0.14.1 Serial3/0/0

10.0.14.1/32 Direct 0 0 D 127.0.0.1 Serial3/0/0

10.0.14.4/32 Direct 0 0 D 10.0.14.4 Serial3/0/0

10.0.14.255/32 Direct 0 0 D 127.0.0.1 Serial3/0/0

10.0.15.0/24 Direct 0 0 D 10.0.15.1 GigabitEthernet0/0/0

10.0.15.1/32 Direct 0 0 D 127.0.0.1 GigabitEthernet0/0/0

10.0.15.255/32 Direct 0 0 D 127.0.0.1 GigabitEthernet0/0/0

10.0.23.0/24 O\_ASE 150 1 D 10.0.15.5 GigabitEthernet0/0/0

10.0.35.0/24 O\_ASE 150 1 D 10.0.15.5 GigabitEthernet0/0/0

10.1.4.0/24 O\_ASE 150 1 D 10.0.15.5 GigabitEthernet0/0/0

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

此时R1上路由10.1.4.0/24的下一跳是R5。

再分别查看R2，R3，R5上路由表中的10.1.4.0/24这条路由。

[R2]display ip routing-table 10.1.4.0

Route Flags: R - relay, D - download to fib

----------------------------------------------------------------------------

Routing Table : Public

Summary Count : 1

Destination/Mask Proto Pre Cost Flags NextHop Interface

10.1.4.0/24 O\_ASE 150 1 D 10.0.12.1 Serial1/0/0

[R3]display ip routing-table 10.1.4.0

Route Flags: R - relay, D - download to fib

------------------------------------------------------------------------------

Routing Table : Public

Summary Count : 1

Destination/Mask Proto Pre Cost Flags NextHop Interface

10.1.4.0/24 ISIS-L2 15 74 D 10.0.23.2 Serial2/0/0

[R5]display ip routing-table 10.1.4.0

Route Flags: R - relay, D - download to fib

------------------------------------------------------------------------------

Routing Table : Public

Summary Count : 1

Destination/Mask Proto Pre Cost Flags NextHop Interface

10.1.4.0/24 ISIS-L2 15 84 D 10.0.35.3 Serial1/0/0

在R1上使用**tracert**命令查看到地址10.1.4.4的路径。

[R1]tracert 10.1.4.4

traceroute to 10.1.4.4(10.1.4.4), max hops: 30 ,packet length: 40,press CTRL\_C to break

1 10.0.15.5 61 ms 2 ms 2 ms

2 10.0.35.3 29 ms 28 ms 29 ms

3 10.0.23.2 31 ms 36 ms 36 ms

4 10.0.12.1 34 ms 36 ms 36 ms

5 10.0.15.5 34 ms 37 ms 37 ms

6 10.0.35.3 55 ms 59 ms 59 ms

7 10.0.23.2 60 ms 66 ms 66 ms

8 10.0.12.1 63 ms 66 ms 66 ms

9 10.0.15.5 65 ms 67 ms 67 ms

此时发现环路。

原因是配置了路由引入后，R5既可以在ISIS域中学习到10.1.4.0/24，也可以在OSPF域中学习到这条路由。

由于ISIS的路由优先级比OSPF外部路由的优先级高，从而导致R5使用了从ISIS域中学习到的路由。

R1能同时从R5和R4学习到这条路由。对于这两条外部路由，同是OSPF外部路由，所以比较二者的cost值。由于R1连接R5的是千兆链路，优于R1连接R4的串行链路，使R1选择使用从R5学习的路由，最终导致环路。

在R5上使用路由策略policy\_r5，给路由10.1.4.0/24打上标记100。

[R5]acl number 2001

[R5-acl-basic-2001]rule 0 permit source 10.1.4.0 0.0.0.255

[R5-acl-basic-2001]quit

[R5]route-policy add\_tag permit node 10

[R5-route-policy]if-match acl 2001

[R5-route-policy]apply tag 100

[R5-route-policy]quit

[R5]route-policy add\_tag permit node 20

[R5-route-policy]quit

[R5]ospf 1

[R5-ospf-1]import-route rip route-policy add\_tag

[R5-ospf-1]quit

在R1上查看OSPF路由信息。

[R1]display ospf routing

OSPF Process 1 with Router ID 10.0.12.1

Routing Tables

Routing for Network

Destination Cost Type NextHop AdvRouter Area

10.0.1.1/32 0 Stub 10.0.1.1 10.0.12.1 0.0.0.0

10.0.12.0/24 1562 Stub 10.0.12.1 10.0.12.1 0.0.0.0

10.0.14.0/24 1562 Stub 10.0.14.1 10.0.12.1 0.0.0.0

10.0.15.0/24 1 Transit 10.0.15.1 10.0.12.1 0.0.0.0

10.0.4.4/32 1562 Stub 10.0.14.4 10.0.14.4 0.0.0.0

Routing for ASEs

Destination Cost Type Tag NextHop AdvRouter

1.1.1.0/24 1 Type2 1 10.0.15.5 10.0.35.5

10.0.2.2/32 1 Type2 1 10.0.15.5 10.0.35.5

10.0.3.3/32 1 Type2 1 10.0.15.5 10.0.35.5

10.0.5.5/32 1 Type2 1 10.0.15.5 10.0.35.5

10.0.14.1/32 1 Type2 1 10.0.15.5 10.0.35.5

10.0.23.0/24 1 Type2 1 10.0.15.5 10.0.35.5

10.0.35.0/24 1 Type2 1 10.0.15.5 10.0.35.5

10.1.4.0/24 1 Type2 100 10.0.15.5 10.0.35.5

Total Nets: 13

Intra Area: 5 Inter Area: 0 ASE: 8 NSSA: 0

在R1上发现携带标记100的10.1.4.0/24路由，再次R1验证是从R5获得这条路由。

为了解决环路问题，在R5上向OSPF引入ISIS路由时，过滤掉路由10.1.4.0/24即可。

在R5上配置路由策略route\_delete，控制向OSPF引入的RIP路由。

[R5]route-policy route\_delete deny node 10

[R5-route-policy]if-match acl 2001

[R5-route-policy]quit

[R5]route-policy route\_delete permit node 20

[R5-route-policy]quit

[R5]ospf 1

[R5-ospf-1]import-route rip route-policy route\_delete

[R5-ospf-1]quit

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 : 28 Routes : 28

Destination/Mask Proto Pre Cost Flags NextHop Interface

1.0.0.0/8 Static 60 0 D 0.0.0.0 NULL0

1.1.0.0/16 Static 60 0 D 0.0.0.0 NULL0

1.1.1.0/24 Static 60 0 D 0.0.0.0 NULL0

1.1.1.0/25 Static 60 0 D 0.0.0.0 NULL0

1.1.1.1/32 Static 60 0 D 0.0.0.0 NULL0

10.0.1.1/32 Direct 0 0 D 127.0.0.1 LoopBack0

10.0.2.2/32 O\_ASE 150 1 D 10.0.15.5 GigabitEthernet0/0/0

10.0.3.3/32 O\_ASE 150 1 D 10.0.15.5 GigabitEthernet0/0/0

10.0.4.4/32 OSPF 10 1562 D 10.0.14.4 Serial3/0/0

10.0.5.5/32 O\_ASE 150 1 D 10.0.15.5 GigabitEthernet0/0/0

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 Serial1/0/0

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 Serial1/0/0

10.0.14.0/24 Direct 0 0 D 10.0.14.1 Serial3/0/0

10.0.14.1/32 Direct 0 0 D 127.0.0.1 Serial3/0/0

10.0.14.4/32 Direct 0 0 D 10.0.14.4 Serial3/0/0

10.0.14.255/32 Direct 0 0 D 127.0.0.1 Serial3/0/0

10.0.15.0/24 Direct 0 0 D 10.0.15.1 GigabitEthernet0/0/0

10.0.15.1/32 Direct 0 0 D 127.0.0.1 GigabitEthernet0/0/0

10.0.15.255/32 Direct 0 0 D 127.0.0.1 GigabitEthernet0/0/0

10.0.23.0/24 O\_ASE 150 1 D 10.0.15.5 GigabitEthernet0/0/0

10.0.35.0/24 O\_ASE 150 1 D 10.0.15.5 GigabitEthernet0/0/0

10.1.4.0/24 O\_ASE 150 1 D 10.0.14.4 Serial3/0/0

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

显示路由信息正常。

测试R1与地址10.1.4.4之间的连通性。

[R1]ping 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=255 time=33 ms

Reply from 10.1.4.4: bytes=56 Sequence=2 ttl=255 time=29 ms

Reply from 10.1.4.4: bytes=56 Sequence=3 ttl=255 time=29 ms

Reply from 10.1.4.4: bytes=56 Sequence=4 ttl=255 time=29 ms

Reply from 10.1.4.4: bytes=56 Sequence=5 ttl=255 time=29 ms

--- 10.1.4.4 ping statistics ---

5 packet(s) transmitted

5 packet(s) received

0.00% packet loss

round-trip min/avg/max = 29/29/33 ms

在R1上检测到达地址10.1.4.4的路径。

缺省情况下，设备的ICMP端口不可达报文的发送功能处于未使能状态，所以我们首先在R4上执行命令icmp port-unreachable send，使能设备的ICMP端口不可达报文的发送功能。

[R4]icmp port-unreachable send

[R1]tracert 10.1.4.4

traceroute to 10.1.4.4(10.1.4.4), max hops: 30 ,packet length: 40,press CTRL\_C to break

1 10.0.14.4 61 ms 29 ms 29 ms

此时环路问题解决，R1上路由10.1.4.0/24的下一跳为R4。

1. 使用Route-policy修改路由优先级避免路由环路

查看R5的路由表。观察路由10.1.4.0/24的下一跳。

[R5]display ip routing-table

Route Flags: R - relay, D - download to fib

------------------------------------------------------------------------------

Routing Tables: Public

Destinations : 22 Routes : 22

Destination/Mask Proto Pre Cost Flags NextHop Interface

1.1.1.0/24 ISIS-L2 15 84 D 10.0.35.3 Serial1/0/0

10.0.1.1/32 OSPF 10 1 D 10.0.15.1 GigabitEthernet

0/0/0

10.0.2.2/32 ISIS-L2 15 20 D 10.0.35.3 Serial1/0/0

10.0.3.3/32 ISIS-L2 15 10 D 10.0.35.3 Serial1/0/0

10.0.4.4/32 OSPF 10 49 D 10.0.15.1 GigabitEthernet

0/0/0

10.0.5.5/32 Direct 0 0 D 127.0.0.1 LoopBack0

10.0.12.0/24 OSPF 10 49 D 10.0.15.1 GigabitEthernet

0/0/0

10.0.14.0/24 OSPF 10 49 D 10.0.15.1 GigabitEthernet

0/0/0

10.0.14.1/32 ISIS-L2 15 84 D 10.0.35.3 Serial1/0/0

10.0.15.0/24 Direct 0 0 D 10.0.15.5 GigabitEthernet

0/0/0

10.0.15.5/32 Direct 0 0 D 127.0.0.1 GigabitEthernet

0/0/0

10.0.15.255/32 Direct 0 0 D 127.0.0.1 GigabitEthernet

0/0/0

10.0.23.0/24 ISIS-L2 15 20 D 10.0.35.3 Serial1/0/0

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 Serial1/0/0

10.0.35.255/32 Direct 0 0 D 127.0.0.1 Serial1/0/0

10.1.4.0/24 ISIS-L2 15 84 D 10.0.35.3 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

在R5上检测到达地址10.1.4.4的路径。

[R5]tracert 10.1.4.4

traceroute to 10.1.4.4(10.1.4.4), max hops: 30 ,packet length: 40,press CTRL\_C to break

1 10.0.35.3 62 ms 24 ms 24 ms

2 10.0.23.2 43 ms 44 ms 44 ms

3 10.0.12.1 33 ms 33 ms 33 ms

4 10.0.14.4 74 ms 55 ms 55 ms

发现通过路由过滤的方法虽然能解决环路问题，但是R5仍旧是从ISIS域学习到路由10.1.4.0/24。显然次优路径问题仍然没有得到解决。

为了解决环路问题以及次优路径问题，阻止R5从ISIS域中获得路由10.1.4.0/24，使R5从OSPF域学习到路由10.1.4.0/24。

删除R5上的策略route\_delete。

[R5]ospf 1

[R5-ospf-1]undo import-route isis

[R5-ospf-1]quit

[R5]undo route-policy route\_delete

[R5]ospf 1

[R5-ospf-1]import-route isis

[R5-ospf-1]quit

在R5上配置策略route\_pref，将10.1.4.0/24的路由优先级修改为180，使其小于OSPF外部路由的路由优先级。

[R5]route-policy route\_pref permit node 10

[R5-route-policy]if-match acl 2001

[R5-route-policy]apply preference 180

[R5-route-policy]quit

使用路由策略route\_pref来控制RIP发布给OSPF的路由。

[R5]isis 1

[R5-isis-1]preference route-policy route\_pref

检查R5，R1的路由表，观察路由10.1.4.0/24的下一跳。

[R5]display ip routing-table 10.1.4.0

Route Flags: R - relay, D - download to fib

----------------------------------------------------------------------------

Routing Table : Public

Summary Count : 1

Destination/Mask Proto Pre Cost Flags NextHop Interface

10.1.4.0/24 O\_ASE 150 1 D 10.0.15.1 GigabitEthernet0/0/0

[R1]display ip routing-table 10.1.4.0

Route Flags: R - relay, D - download to fib

----------------------------------------------------------------------------

Routing Table : Public

Summary Count : 1

Destination/Mask Proto Pre Cost Flags NextHop Interface

10.1.4.0/24 O\_ASE 150 1 D 10.0.14.4 Serial3/0/0

检查R1与地址10.1.4.4的连通性。

[R1]ping 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=255 time=39 ms

Reply from 10.1.4.4: bytes=56 Sequence=2 ttl=255 time=35 ms

Reply from 10.1.4.4: bytes=56 Sequence=3 ttl=255 time=35 ms

Reply from 10.1.4.4: bytes=56 Sequence=4 ttl=255 time=35 ms

Reply from 10.1.4.4: bytes=56 Sequence=5 ttl=255 time=35 ms

--- 10.1.4.4 ping statistics ---

5 packet(s) transmitted

5 packet(s) received

0.00% packet loss

round-trip min/avg/max = 35/35/39 ms

在R1上检测到达地址10.1.4.4的路径。

[R1]tracert 10.1.4.4

traceroute to 10.1.4.4(10.1.4.4), max hops: 30 ,packet length: 40,press CTRL\_C to break

1 10.0.14.4 61 ms 25 ms 25 ms

在R5上检测到达地址10.1.4.4的路径。

[R5]tracert 10.1.4.4

traceroute to 10.1.4.4(10.1.4.4), max hops: 30 ,packet length: 40,press CTRL\_C to break

1 10.0.15.1 61 ms 2 ms 2 ms

2 10.0.14.4 41 ms 28 ms 27 ms

此时环路问题解决。

在R1上，路由10.1.4.0/24的下一跳是R4。在R5上，路由10.1.4.0/24的下一跳是R1。次优路由也得到解决。

## **附加实验: 思考并验证**

在步骤三中，思考通过访问控制列表是否可以实现同样的效果，它和前缀列表的区别又是什么。

在步骤五中，思考为什么R3路由表中的10.0.15.0/24出现有两个下一跳，而10.0.12.0/24只有一个下一跳。

## **最终设备配置**

<R1>**display current-configuration**

[V200R007C00SPC600]

#

sysname R1

#

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 GigabitEthernet0/0/0

ip address 10.0.15.1 255.255.255.0

#

interface LoopBack0

ip address 10.0.1.1 255.255.255.255

#

ospf 1

import-route static route-policy policy\_r1

area 0.0.0.0

network 10.0.12.1 0.0.0.0

network 10.0.15.1 0.0.0.0

network 10.0.14.1 0.0.0.0

network 10.0.1.1 0.0.0.0

#

route-policy policy\_r1 permit node 10

if-match ip-prefix pref\_r1

#

ip ip-prefix pref\_r1 index 10 permit 1.1.1.0 24 greater-equal 24 less-equal 24

#

ip route-static 1.0.0.0 255.0.0.0 NULL0

ip route-static 1.1.0.0 255.255.0.0 NULL0

ip route-static 1.1.1.0 255.255.255.0 NULL0

ip route-static 1.1.1.0 255.255.255.128 NULL0

ip route-static 1.1.1.1 255.255.255.255 NULL0

#

return

<R2>**display current-configuration**

[V200R007C00SPC600]

#

sysname R2

#

isis 1

is-level level-2

network-entity 49.0001.0000.0000.0002.00

import-route ospf 1

#

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

isis enable 1

#

interface LoopBack0

ip address 10.0.2.2 255.255.255.255

isis enable 1

#

ospf 1

area 0.0.0.0

network 10.0.12.2 0.0.0.0

#

return

<R3>**display current-configuration**

[V200R007C00SPC600]

#

sysname R3

#

isis 1

is-level level-2

network-entity 49.0001.0000.0000.0003.00

#

interface Serial2/0/0

link-protocol ppp

ip address 10.0.23.3 255.255.255.0

isis enable 1

#

interface Serial3/0/0

link-protocol ppp

ip address 10.0.35.3 255.255.255.0

isis enable 1

#

interface LoopBack0

ip address 10.0.3.3 255.255.255.255

isis enable 1

<R4>**display current-configuration**

[V200R007C00SPC600]

#

sysname R4

#

icmp port-unreachable send

#

interface Serial1/0/0

link-protocol ppp

ip address 10.0.14.4 255.255.255.0

#

interface LoopBack0

ip address 10.0.4.4 255.255.255.255

#

interface LoopBack1

ip address 10.1.4.4 255.255.255.0

#

ospf 1

import-route direct

area 0.0.0.0

network 10.0.14.4 0.0.0.0

network 10.0.4.4 0.0.0.0

#

return

<R5>**display current-configuration**

[V200R007C00SPC600]

#

sysname R5

#

isis 1

is-level level-2

network-entity 49.0001.0000.0000.0005.00

preference route-policy route\_pref

#

interface Serial1/0/0

link-protocol ppp

ip address 10.0.35.5 255.255.255.0

isis enable 1

#

interface GigabitEthernet0/0/0

ip address 10.0.15.5 255.255.255.0

#

interface LoopBack0

ip address 10.0.5.5 255.255.255.255

isis enable 1

#

ospf 1

import-route rip 1 route-policy route\_delete

area 0.0.0.0

network 10.0.15.5 0.0.0.0

#

route-policy add\_tag permit node 10

if-match acl 2001

apply tag 100

#

route-policy add\_tag permit node 20

#

route-policy route\_pref permit node 10

if-match acl 2001

apply preference 180

#

return

第五章 组播协议

实验 5-1 组播、IGMP及PIM DM协议

学习目的

* 掌握路由器启动组播路由功能的配置方法
* 掌握配置接口IGMP功能的方法
* 掌握PIM DM的配置方法
* 掌握查看和测试组播的方法
* 掌握PIM一些高级特性的配置方法

## **拓扑图**

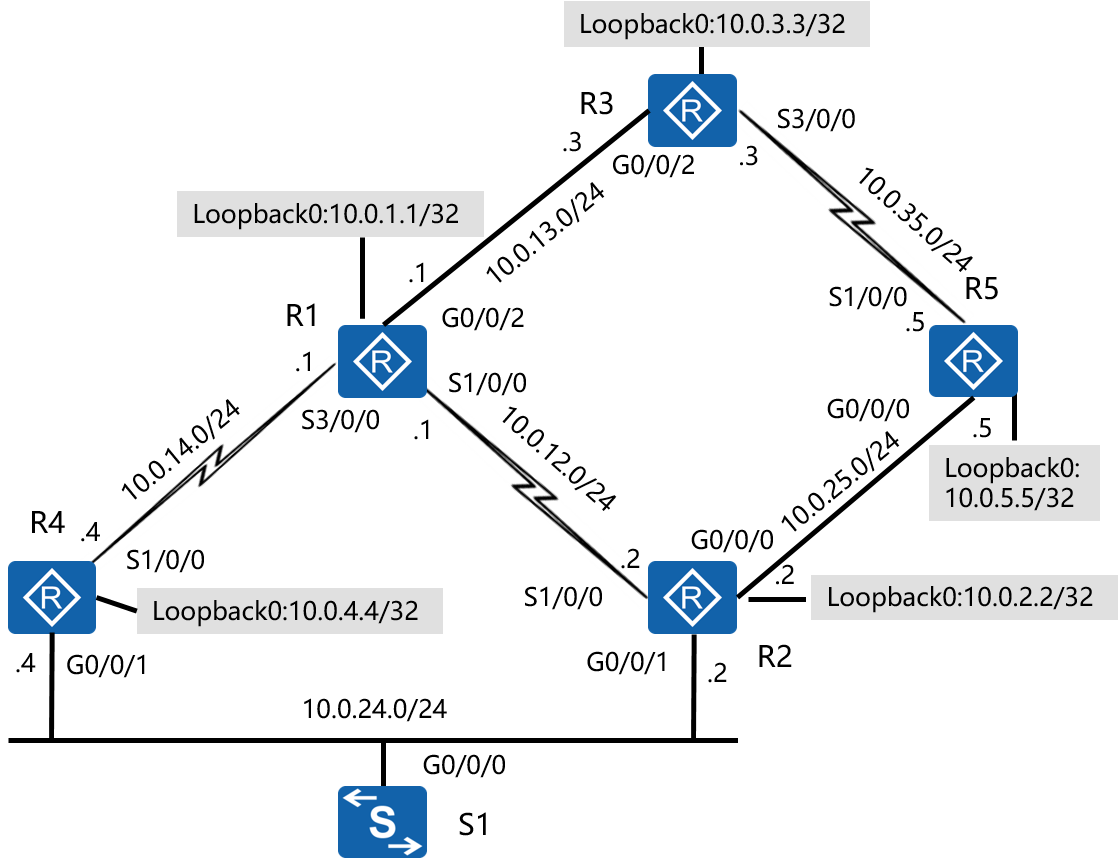


图5-1 组播、IGMP及PIM DM协议

## **场景**

你是公司的网络管理员。公司准备使用组播来进行一些业务的转发。在当前网络上，网络规模较小，你决定使用PIM的DM模式来实现组播路由信息的学习。组播转发的实现过程中，你需要考虑到主机应用对IGMP不同版本的兼容，同时需要考虑使用合适的方式测试网络中组播是否正常工作。为了提升网络的效率和安全性，你采用了PIM DM的一些手段，包括PIM邻居的控制、嫁接和其他安全措施。同时实现网络的组播转发之前，你也遇到了一些网络故障，经过一些故障排除步骤，最终网络正常工作了。

学习任务

1. 基础配置与IP编址

首先，如果采用真机的实验环境，为防止路由器收到其他网段的组播报文，建议对S2交换机（实现R1和R3的互联）做如下配置（如果是eNSP模拟器环境，则不需要进行下列配置）：

<Huawei>system-view

Enter system view, return user view with Ctrl+Z.

[Huawei]sysname S2

[S2]vlan 13

[S2-vlan13]quit

[S2]int GigabitEthernet 0/0/1

[S2-GigabitEthernet0/0/1]port link-t access

[S2-GigabitEthernet0/0/1]port default vlan 13

[S2-GigabitEthernet0/0/1]quit

[S2]int GigabitEthernet 0/0/3

[S2-GigabitEthernet0/0/3]port link-t access

[S2-GigabitEthernet0/0/3]port default vlan 13

[S2-GigabitEthernet0/0/3]quit

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。

<Huawei>system-view

Enter system view, return user view with Ctrl+Z.

[Huawei]sysname R1

[R1]interface Serial 1/0/0

[R1-Serial1/0/0]ip address 10.0.12.1 24

[R1-Serial1/0/0]quit

[R1]interface Serial 3/0/0

[R1-Serial3/0/0]ip address 10.0.14.1 24

[R1-Serial3/0/0]quit

[R1]interface GigabitEthernet 0/0/2

[R1-GigabitEthernet0/0/2]ip address 10.0.13.1 24

[R1-GigabitEthernet0/0/2]quit

[R1]interface LoopBack 0

[R1-LoopBack0]ip address 10.0.1.1 32

[R1-LoopBack0]quit

<Huawei>system-view

Enter system view, return user view with Ctrl+Z.

[Huawei]sysname R2

[R2]interface Serial 1/0/0

[R2-Serial1/0/0]ip address 10.0.12.2 24

[R2-Serial1/0/0]quit

[R2]interface GigabitEthernet 0/0/0

[R2-GigabitEthernet0/0/0]ip address 10.0.25.2 24

[R2-GigabitEthernet0/0/0]quit

[R2]interface GigabitEthernet 0/0/1

[R2-GigabitEthernet0/0/1]ip address 10.0.24.2 24

[R2-GigabitEthernet0/0/1]quit

[R2]interface LoopBack 0

[R2-LoopBack0]ip address 10.0.2.2 32

[R2-LoopBack0]quit

<Huawei>system-view

Enter system view, return user view with Ctrl+Z.

[Huawei]sysname R3

[R3]interface GigabitEthernet 0/0/2

[R3-GigabitEthernet0/0/2]ip address 10.0.13.3 24

[R3-GigabitEthernet0/0/2]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 32

[R3-LoopBack0]quit

<Huawei>system-view

Enter system view, return user view with Ctrl+Z.

[Huawei]sysname R4

[R4]interface Serial 1/0/0

[R4-Serial1/0/0]ip address 10.0.14.4 24

[R4-Serial1/0/0]quit

[R4]interface GigabitEthernet 0/0/1

[R4-GigabitEthernet0/0/1]ip address 10.0.24.4 24

[R4-GigabitEthernet0/0/1]quit

[R4]interface LoopBack 0

[R4-LoopBack0]ip address 10.0.4.4 32

[R4-LoopBack0]quit

<Huawei>system-view

Enter system view, return user view with Ctrl+Z.

[Huawei]sysname R5

[R5]interface Serial 1/0/0

[R5-Serial1/0/0]ip address 10.0.35.5 24

[R5-Serial1/0/0]quit

[R5]interface GigabitEthernet 0/0/0

[R5-GigabitEthernet0/0/0]ip address 10.0.25.5 24

[R5-GigabitEthernet0/0/0]quit

[R5]interface LoopBack 0

[R5-LoopBack0]ip address 10.0.5.5 32

[R5-LoopBack0]quit

配置完成以后，验证路由器之间的连通性。

[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=5 ms

--- 10.0.13.3 ping statistics ---

1 packet(s) transmitted

1 packet(s) received

0.00% packet loss

round-trip min/avg/max = 5/5/5 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

[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=38 ms

--- 10.0.14.4 ping statistics ---

1 packet(s) transmitted

1 packet(s) received

0.00% packet loss

round-trip min/avg/max = 38/38/38 ms

[R5]ping -c 1 10.0.35.3

PING 10.0.35.3: 56 data bytes, press CTRL\_C to break

Reply from 10.0.35.3: bytes=56 Sequence=1 ttl=255 time=33 ms

--- 10.0.35.3 ping statistics ---

1 packet(s) transmitted

1 packet(s) received

0.00% packet loss

round-trip min/avg/max = 33/33/33 ms

[R5]ping -c 1 10.0.25.2

PING 10.0.25.2: 56 data bytes, press CTRL\_C to break

Reply from 10.0.25.2: bytes=56 Sequence=1 ttl=255 time=10 ms

--- 10.0.25.2 ping statistics ---

1 packet(s) transmitted

1 packet(s) received

0.00% packet loss

round-trip min/avg/max = 10/10/10 ms

1. 配置所有路由器启用组播路由功能

启用R1、R2、R3、R4及R5的组播路由功能。要开启组播功能，首先在系统视图下运行命令**multicast routing-enable**。

默认情况下，VRP平台的组播功能是关闭的。无论要使用PIM还是IGMP都需要先在全局下开启组播功能。

[R1]multicast routing-enable

对于要运行PIM DM的接口，在接口视图下运行**pim dm**开启组播路由协议。

[R1]interface GigabitEthernet 0/0/2

[R1-GigabitEthernet0/0/2]pim dm

[R1-GigabitEthernet0/0/2]quit

[R1]interface Serial 1/0/0

[R1-Serial1/0/0]pim dm

[R1-Serial1/0/0]quit

[R1]interface Serial 3/0/0

[R1-Serial3/0/0]pim dm

[R1-Serial3/0/0]quit

在R2、R3、R4、R5上进行相同的配置，注意在路由器与路由器的互联接口上开启PIM DM的功能。

[R2]multicast routing-enable

[R2]interface Serial 1/0/0

[R2-Serial1/0/0]pim dm

[R2-Serial1/0/0]quit

[R2]interface GigabitEthernet 0/0/0

[R2-GigabitEthernet0/0/0]pim dm

[R2-GigabitEthernet0/0/0]quit

[R3]multicast routing-enable

[R3]interface GigabitEthernet 0/0/2

[R3-GigabitEthernet0/0/2]pim dm

[R3-GigabitEthernet0/0/2]quit

[R3]interface Serial 3/0/0

[R3-Serial3/0/0]pim dm

[R3-Serial3/0/0]quit

[R4]multicast routing-enable

[R4]interface Serial 1/0/0

[R4-Serial1/0/0]pim dm

[R4-Serial1/0/0]quit

[R4]interface GigabitEthernet 0/0/1

[R4-GigabitEthernet0/0/1]pim dm

[R4-GigabitEthernet0/0/1]quit

[R5]multicast routing-enable

[R5]interface Serial 1/0/0

[R5-Serial1/0/0]pim dm

[R5-Serial1/0/0]quit

[R5]interface GigabitEthernet 0/0/0

[R5-GigabitEthernet0/0/0]pim dm

[R5-GigabitEthernet0/0/0]quit

配置完成后，查看路由器PIM在接口上的运行状态。

[R1]display pim interface

VPN-Instance: public net

Interface State NbrCnt HelloInt DR-Pri DR-Address

GE0/0/2 up 1 30 1 10.0.13.3

S1/0/0 up 1 30 1 10.0.12.2

S3/0/0 up 1 30 1 10.0.14.4

可以看到R1有3个接口运行了PIM，并且在每个接口上各有一个邻居（NbrCnt），同时我们还可以发现，在一个网段上接口IP地址较大的路由器将成为这个网段的DR。

查看R1上接口G0/0/2的PIM详细信息。

[R1]display pim interface GigabitEthernet 0/0/2 verbose

VPN-Instance: public net

Interface: GigabitEthernet0/0/2, 10.0.13.1

PIM version: 2

PIM mode: Dense

PIM state: up

PIM DR: 10.0.13.3

PIM DR Priority (configured): 1

PIM neighbor count: 1

PIM hello interval: 30 s

PIM LAN delay (negotiated): 500 ms

PIM LAN delay (configured): 500 ms

PIM hello override interval (negotiated): 2500 ms

PIM hello override interval (configured): 2500 ms

PIM Silent: disabled

PIM neighbor tracking (negotiated): disabled

PIM neighbor tracking (configured): disabled

PIM join attribute (negotiated): disabled

PIM generation ID: 0X53201C1B

PIM require-GenID: disabled

PIM hello hold interval: 105 s

PIM assert hold interval: 180 s

PIM triggered hello delay: 5 s

PIM J/P interval: 60 s

PIM J/P hold interval: 210 s

PIM state-refresh processing: enabled

PIM state-refresh interval: 60 s

PIM graft retry interval: 3 s

PIM state-refresh capability on link: capable

PIM BFD: disabled

PIM dr-switch-delay timer: not configured

Number of routers on link not using DR priority: 0

Number of routers on link not using LAN delay: 0

Number of routers on link not using neighbor tracking: 2

Number of routers on link not using join attribute: 2

ACL of PIM neighbor policy: -

ACL of PIM ASM join policy: -

ACL of PIM SSM join policy: -

ACL of PIM join policy: -

可以看到PIM DM默认的Hello间隔是30秒，Hello的保持时间是Hello间隔的3.5倍，也就是105秒。

查看R1的邻居列表，共有3台路由器与R1形成PIM邻居关系，邻居默认的DR优先级均为1。

[R1]display pim neighbor

VPN-Instance: public net

Total Number of Neighbors = 3

Neighbor Interface Uptime Expires Dr-Priority BFD-Session

10.0.13.3 GE0/0/2 00:09:02 00:01:16 1 N

10.0.12.2 S1/0/0 00:17:01 00:01:43 1 N

10.0.14.4 S3/0/0 00:16:08 00:01:37 1 N

查看邻居R3的详细信息，Uptime表示邻居关系已经建立的时间，Expiry time表示PIM邻居还有多少时间就要超时，LAN delay表示传递Prune剪枝消息的延迟时间，Override interval表示否决Prune剪枝的时间间隔。

[R1]display pim neighbor 10.0.13.3 verbose

VPN-Instance: public net

Neighbor: 10.0.13.3

Interface: GigabitEthernet0/0/2

Uptime: 00:40:11

Expiry time: 00:01:37

DR Priority: 1

Generation ID: 0X9AF72165

Holdtime: 105 s

LAN delay: 500 ms

Override interval: 2500 ms

State refresh interval: 60 s

Neighbor tracking: Disabled

PIM join attribute: Disabled

PIM BFD-Session: N

1. 配置IGMP

在这个实验中，我们模拟组播用户连接在交换机S1上。在R2和R4的G0/0/1接口开启IGMP功能。要开启IGMP的功能，在接口模式下运行**igmp enable**。

[R2]interface GigabitEthernet 0/0/1

[R2-GigabitEthernet0/0/1]igmp enable

[R2-GigabitEthernet0/0/1]quit

[R4]interface GigabitEthernet 0/0/1

[R4-GigabitEthernet0/0/1]igmp enable

[R4-GigabitEthernet0/0/1]quit

为了实验需要，在R2和R4的G0/0/1接口添加静态组播组。这样，该接口始终会转发目的地址为225.1.1.1的组播流量。

[R2]interface GigabitEthernet 0/0/1

[R2-GigabitEthernet0/0/1]igmp static-group 225.1.1.1

[R2-GigabitEthernet0/0/0]quit

[R4]interface GigabitEthernet 0/0/1

[R4-GigabitEthernet0/0/1]igmp static-group 225.1.1.1

[R4-GigabitEthernet0/0/1]quit

默认情况下，VRP平台使用的IGMP版本为v2。从下面的输出中可以看到现在G0/0/1接口所在网段的查询器是10.0.24.2，即为R2。对于IGMP v2来说，选取网段上IP地址较小的那台路由器作为查询器。

[R2]display igmp interface GigabitEthernet 0/0/1

Interface information of VPN-Instance: public net

GigabitEthernet0/0/1(10.0.24.2):

IGMP is enabled

Current IGMP version is 2

IGMP state: up

IGMP group policy: none

IGMP limit: -

Value of query interval for IGMP (negotiated): -

Value of query interval for IGMP (configured): 60 s

Value of other querier timeout for IGMP: 0 s

Value of maximum query response time for IGMP: 10 s

Querier for IGMP: 10.0.24.2 (this router)

[R4]display igmp interface GigabitEthernet 0/0/1

Interface information of VPN-Instance: public net

GigabitEthernet0/0/1(10.0.24.4):

IGMP is enabled

Current IGMP version is 2

IGMP state: up

IGMP group policy: none

IGMP limit: -

Value of query interval for IGMP (negotiated): -

Value of query interval for IGMP (configured): 60 s

Value of other querier timeout for IGMP: 104 s

Value of maximum query response time for IGMP: 10 s

Querier for IGMP: 10.0.24.2

在R2上查看接口的静态IGMP组，可以看到225.1.1.1这个组是刚才我们手工添加的组播组。

[R2]display igmp group static

Static join group information

Total 1 entry, Total 1 active entry

Group Address Source Address Interface State Expires

225.1.1.1 0.0.0.0 GE0/0/1 UP never

在接口下查看IGMP路由表。

[R2]display igmp routing-table

Routing table of VPN-Instance: public net

Routing table

Total 1 entry

00001. (\*, 225.1.1.1)

List of 1 downstream interface

GigabitEthernet0/0/1 (10.0.24.2),

Protocol: STATIC

若在接口上只配置了IGMP，没有配置PIM，且接口为查询器的情况下，才会生成IGMP路由表项。该路由表条目在R4上是看不到的，因为现在R2是网段10.0.24.0/24的查询器。

默认情况下，查询器的查询周期为60秒，为了加快用户加入组播组的速度，我们可以通过**igmp timer query**修改发送查询报文的时间间隔。

[R2]interface GigabitEthernet 0/0/1

[R2-GigabitEthernet0/0/1]igmp timer query 20

[R2-GigabitEthernet0/0/1]quit

配置完成以后，验证配置已生效。

[R2]display igmp interface GigabitEthernet 0/0/1

Interface information of VPN-Instance: public net

GigabitEthernet0/0/1(10.0.24.2):

IGMP is enabled

Current IGMP version is 2

IGMP state: up

IGMP group policy: none

IGMP limit: -

Value of query interval for IGMP (negotiated): -

Value of query interval for IGMP (configured): 20 s

Value of other querier timeout for IGMP: 0 s

Value of maximum query response time for IGMP: 10 s

Querier for IGMP: 10.0.24.2 (this router)

开启Debugging后可以看到接口每隔20秒发送一次成员关系查询（general query）。

<R2>terminal monitor

<R2>terminal debugging

<R2>debugging igmp query send

Nov 17 2016 12:33:03.390.1+00:00 R2 IGMP/7/QUERY:(public net): Send version 2 general query on GigabitEthernet0/0/1(10.0.24.2) to destination 224.0.0.1 (G073969)

Nov 17 2016 12:33:23.380.1+00:00 R2 IGMP/7/QUERY:(public net): Send version 2 general query on GigabitEthernet0/0/1(10.0.24.2) to destination 224.0.0.1 (G073969)

Nov 17 2016 12:33:43.360.1+00:00 R2 IGMP/7/QUERY:(public net): Send version 2 general query on GigabitEthernet0/0/1(10.0.24.2) to destination 224.0.0.1 (G073969)

<R2>undo debugging all

Info: All possible debugging has been turned off

路由器的健壮系数描述了IGMP路由器的健壮程度。路由器默认的健壮系数为2，这里通过关闭接口的方式测试健壮系数。首先观察默认情况下IGMP查询消息的间隔。

<R2>terminal monitor

<R2>terminal debugging

<R2>debugging igmp query send

Nov 17 2016 14:26:13.880.1+00:00 R2 IGMP/7/QUERY:(public net): Send version 2 general query on GigabitEthernet0/0/1(10.0.24.2) to destination 224.0.0.1 (G073969)

<R2>

Nov 17 2016 14:26:33.890.1+00:00 R2 IGMP/7/QUERY:(public net): Send version 2 general query on GigabitEthernet0/0/1(10.0.24.2) to destination 224.0.0.1 (G073969)

<R2>system-view

[R2]interface GigabitEthernet 0/0/1

[R2-GigabitEthernet0/0/1]shutdown

[R2-GigabitEthernet0/0/1]undo shutdown

Nov 17 2016 14:26:51.810.1+00:00 R2 IGMP/7/QUERY:(public net): Send version 2 general query on GigabitEthernet0/0/1(10.0.24.2) to destination 224.0.0.1 (G073969)

[R2-GigabitEthernet0/0/1]

Nov 17 2016 14:26:56.790.1+00:00 R2 IGMP/7/QUERY:(public net): Send version 2 general query on GigabitEthernet0/0/1(10.0.24.2) to destination 224.0.0.1 (G073969)

[R2-GigabitEthernet0/0/1]

Nov 17 2016 14:27:16.790.1+00:00 R2 IGMP/7/QUERY:(public net): Send version 2 general query on GigabitEthernet0/0/1(10.0.24.2) to destination 224.0.0.1 (G073969)

[R2-GigabitEthernet0/0/1]

Nov 17 2016 14:27:36.770.1+00:00 R2 IGMP/7/QUERY:(public net): Send version 2 general query on GigabitEthernet0/0/1(10.0.24.2) to destination 224.0.0.1 (G073969)

在没有关闭接口之前，路由器的接口仍按照每20秒一次的间隔发送普遍查询消息，当接口被关闭又重新打开之后，前面2个查询报文的时间间隔为5秒。当路由器启动时会发送“健壮系数”次的“普遍组查询消息”，发送间隔是“IGMP普遍组查询消息的发送间隔”的1/4。

执行命令**robust-count**可配置IGMP健壮系数，注意该参数只有在IGMP v2和IGMP v3中才有效，在R2的G0/0/1上将健壮系数修改为3。

[R2-GigabitEthernet0/0/1]igmp robust-count 3

再使用Debugging观察普遍查询消息的发送。

[R2-GigabitEthernet0/0/1]shutdown

[R2-GigabitEthernet0/0/1]undo shutdown

Nov 17 2016 14:33:07.420.1+00:00 R2 IGMP/7/QUERY:(public net): Send version 2 general query on GigabitEthernet0/0/1(10.0.24.2) to destination 224.0.0.1 (G073969)

[R2-GigabitEthernet0/0/1]

Nov 17 2016 14:33:12.340.1+00:00 R2 IGMP/7/QUERY:(public net): Send version 2 general query on GigabitEthernet0/0/1(10.0.24.2) to destination 224.0.0.1 (G073969)

[R2-GigabitEthernet0/0/1]

Nov 17 2016 14:33:17.340.1+00:00 R2 IGMP/7/QUERY:(public net): Send version 2 general query on GigabitEthernet0/0/1(10.0.24.2) to destination 224.0.0.1 (G073969)

[R2-GigabitEthernet0/0/1]

Nov 17 2016 14:33:37.420.1+00:00 R2 IGMP/7/QUERY:(public net): Send version 2 general query on GigabitEthernet0/0/1(10.0.24.2) to destination 224.0.0.1 (G073969)

[R2-GigabitEthernet0/0/1]return

<R2>undo debugging all

Info: All possible debugging has been turned off

可以看到当健壮系数修改为3以后，当接口启用后前3个普遍组查询消息的时间间隔为5秒，从第四个普遍组查询消息开始时间间隔为20秒。

1. 观察组播路由表

为了观察组播路由的传递，在该拓扑上启用OSPF作为单播路由协议。

[R1]ospf 1 router-id 10.0.1.1

[R1-ospf-1]area 0

[R1-ospf-1-area-0.0.0.0]network 10.0.1.1 0.0.0.0

[R1-ospf-1-area-0.0.0.0]network 10.0.14.1 0.0.0.0

[R1-ospf-1-area-0.0.0.0]network 10.0.13.1 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]quit

[R1-ospf-1]quit

[R2]ospf 1 router-id 10.0.2.2

[R2-ospf-1]area 0

[R2-ospf-1-area-0.0.0.0]network 10.0.2.2 0.0.0.0

[R2-ospf-1-area-0.0.0.0]network 10.0.25.2 0.0.0.0

[R2-ospf-1-area-0.0.0.0]network 10.0.12.2 0.0.0.0

[R2-ospf-1-area-0.0.0.0]quit

[R2-ospf-1]quit

[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 10.0.13.3 0.0.0.0

[R3-ospf-1-area-0.0.0.0]network 10.0.35.3 0.0.0.0

[R3-ospf-1-area-0.0.0.0]quit

[R3-ospf-1]quit

[R4]ospf 1 router-id 10.0.4.4

[R4-ospf-1]area 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]network 10.0.14.4 0.0.0.0

[R4-ospf-1-area-0.0.0.0]quit

[R4-ospf-1]quit

[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]network 10.0.25.5 0.0.0.0

[R5-ospf-1-area-0.0.0.0]network 10.0.35.5 0.0.0.0

[R5-ospf-1-area-0.0.0.0]quit

[R5-ospf-1]quit

配置完成以后，检查各路由器已能学习到其他路由器的Loopback地址。

[R2]display ip routing-table protocol ospf

Route Flags: R - relay, D - download to fib

----------------------------------------------------------------------------

Public routing table : OSPF

Destinations : 7 Routes : 8

OSPF routing table status : <Active>

Destinations : 7 Routes : 8

Destination/Mask Proto Pre Cost Flags NextHop Interface

10.0.1.1/32 OSPF 10 1562 D 10.0.12.1 Serial1/0/0

10.0.3.3/32 OSPF 10 1563 D 10.0.12.1 Serial1/0/0

OSPF 10 1563 D 10.0.25.5 GigabitEthernet0/0/0

10.0.4.4/32 OSPF 10 3124 D 10.0.12.1 Serial1/0/0

10.0.5.5/32 OSPF 10 1 D 10.0.25.5 GigabitEthernet0/0/0

10.0.13.0/24 OSPF 10 1563 D 10.0.12.1 Serial1/0/0

10.0.14.0/24 OSPF 10 3124 D 10.0.12.1 Serial1/0/0

10.0.35.0/24 OSPF 10 1563 D 10.0.25.5 GigabitEthernet0/0/0

OSPF routing table status : <Inactive>

Destinations : 0 Routes : 0

为了模拟组播信息的传递，我们在R3上以自己的Loopback接口作为源地址，向目的地址225.1.1.1发送Ping数据包，模拟组播源。

[R3]ping -a 10.0.3.3 -c 300 225.1.1.1

间隔几分钟后，我们可以在其他所有路由器上看到组播路由表。在R2上查看组播路由表。

[R2]display pim routing-table

VPN-Instance: public net

Total 1(\*, G) entry; 1 (S, G) entry

(\*, 225.1.1.1)

Protocol: pim-dm, Flag: WC EXT

UpTime: 00:09:04

Upstream interface: NULL

Upstream neighbor: NULL

RPF prime neighbor: NULL

Downstream interface(s) information: None

(10.0.3.3, 225.1.1.1)

Protocol: pim-dm, Flag:

UpTime: 00:00:52

Upstream interface: GigabitEthernet0/0/0

Upstream neighbor: 10.0.25.5

RPF prime neighbor: 10.0.25.5

Downstream interface(s) information: None

可以看到2个条目。

第一个条目(\*, 225.1.1.1)为该接口配置了静态IGMP组产生的。

第二个条目(10.0.3.3, 225.1.1.1)为组播流量进行扩散后在该路由器上产生的条目。

从输出中我们还可以看到对于R2来说，该组播流的上游路由器为10.0.25.5。

启用了PIM以后，路由器会采用单播路由表进行RPF检查，从下面的输出中可以看到，对于组播源10.0.3.3，RPF的邻居是10.0.25.5。

[R2]display multicast rpf-info 10.0.3.3

VPN-Instance: public net

RPF information about source: 10.0.3.3

RPF interface: GigabitEthernet0/0/0, RPF neighbor: 10.0.25.5

Referenced route/mask: 10.0.3.3/32

Referenced route type: unicast

Route selection rule: preference-preferred

Load splitting rule: disable

1. 调整PIM DM参数

有时我们希望流量不按照单播路由的路径流向目的地，就可以通过**rpf-route-static**静态修改RPF路径。这个试验中，我们把RPF路径由原来的10.0.25.5修改为10.0.12.1。

[R2]ip rpf-route-static 10.0.3.0 255.255.255.0 10.0.12.1

配置完成以后，可验证RPF邻居已变成了10.0.12.1。

[R2]display multicast rpf-info 10.0.3.3

VPN-Instance: public net

RPF information about source: 10.0.3.3

RPF interface: Serial1/0/0, RPF neighbor: 10.0.12.1

Referenced route/mask: 10.0.3.0/24

Referenced route type: mstatic

Route selection rule: preference-preferred

Load splitting rule: disable

为了观察PIM的剪枝及嫁接消息，我们通过删除及添加IGMP静态组的方式来模拟用户的离开及加入。首先在R2上打开Debugging。

<R1>terminal monitor

<R2>terminal debugging

<R2>debugging pim join-prune

然后把R2的静态IGMP组225.1.1.1删除。

<R2>system-view

[R2]interface GigabitEthernet 0/0/1

[R2-GigabitEthernet0/0/1]undo igmp static-group 225.1.1.1

Nov 17 2016 15:00:05.300.1+00:00 R2 PIM/7/JP:(public net): PIM ver 2 JP sending 10.0.12.2 -> 224.0.0.13 on Serial1/0/0 (P012689)

Nov 17 2016 15:00:05.300.2+00:00 R2 PIM/7/JP:(public net): Upstream 10.0.12.1, Groups 1, Holdtime 210 (P012693)

Nov 17 2016 15:00:05.300.3+00:00 R2 PIM/7/JP:(public net): Group: 225.1.1.1/32 --- 0 joins 1 prunes (P012701)

Nov 17 2016 15:00:05.310.1+00:00 R2 PIM/7/JP:(public net): Prune: 10.0.3.3/32 (P012707)

Nov 17 2016 15:00:05.350.1+00:00 R2 PIM/7/JP:(public net): PIM ver 2 JP receiving 10.0.12.1 -> 224.0.0.13 on Serial1/0/0 (P012689)

Nov 17 2016 15:00:05.350.2+00:00 R2 PIM/7/JP:(public net): Upstream 10.0.12.1, Groups 1, Holdtime 207 (P012693)

Nov 17 2016 15:00:05.350.3+00:00 R2 PIM/7/JP:(public net): Group: 225.1.1.1/32 --- 0 joins 1 prunes (P012701)

Nov 17 2016 15:00:05.350.4+00:00 R2 PIM/7/JP:(public net): Prune: 10.0.3.3/32 (P012707)

可以看到R2立刻以组播地址224.0.0.13向上游接口发送剪枝消息，上游路由器的地址为10.0.12.1，此时225.1.1.1这个组播组已被剪枝。随后R1向R2发送消息确认剪枝。

然后再把刚才删除的静态IGMP组播组添加回去。

[R2-GigabitEthernet0/0/1]igmp static-group 225.1.1.1

Nov 17 2016 15:00:19.440.1+00:00 R2 PIM/7/JP:(public net): PIM ver 2 GFT sending 10.0.12.2 -> 10.0.12.1 on Serial1/0/0 (P012633)

Nov 17 2016 15:00:19.440.2+00:00 R2 PIM/7/JP:(public net): Upstream 10.0.12.1, Groups 1, Holdtime 0 (P012639)

Nov 17 2016 15:00:19.440.3+00:00 R2 PIM/7/JP:(public net): Group: 225.1.1.1/32 --- 1 joins 0 prunes (P012648)

Nov 17 2016 15:00:19.440.4+00:00 R2 PIM/7/JP:(public net): Join: 10.0.3.3/32 (P012654)

Nov 17 2016 15:00:19.480.1+00:00 R2 PIM/7/JP:(public net): PIM ver 2 GAK receiving 10.0.12.1 -> 10.0.12.2 on Serial1/0/0 (P012633)

Nov 17 2016 15:00:19.480.2+00:00 R2 PIM/7/JP:(public net): Upstream 10.0.12.2, Groups 1, Holdtime 0 (P012639)

Nov 17 2016 15:00:19.480.3+00:00 R2 PIM/7/JP:(public net): Group: 225.1.1.1/32 --- 1 joins 0 prunes (P012648)

Nov 17 2016 15:00:19.480.4+00:00 R2 PIM/7/JP:(public net): Join: 10.0.3.3/32 (P012654)

[R2-GigabitEthernet0/0/1]return

<R2>undo debugging all

Info: All possible debugging has been turned off

这时R2立刻向上游以单播的形式发送了嫁接消息，加入225.1.1.1，同时R1也以单播的形式向R2回应了嫁接确认。

从这里可以总结出：**剪枝消息是以组播地址224.0.0.13发送的，而嫁接消息是以单播向上游发送的。**

有时我们希望组播流量只在规定的范围内传递，这时候可以在接口下通过**multicast boundary**为某个特定的组播组或组播地址段定界。

控制组播组225.1.1.2的流量不要传递到R4上，在R1连接到R4的接口上增加如下配置。

[R1]interface Serial 3/0/0

[R1-Serial3/0/0]multicast boundary 225.1.1.2 255.255.255.255

[R1-Serial3/0/0]quit

在R3上模拟目的地址为225.1.1.2的组播流量。

[R3]ping -a 10.0.3.3 -c 300 225.1.1.2

等待在R2和R4上分别查看组播路由表，可以看到在R2上存在表项(10.0.3.3, 225.1.1.2)，而在R4上没有该组播组路由条目，说明组播流量并没有扩散到R4上。

[R2]display pim routing-table

VPN-Instance: public net

Total 1 (\*, G) entry; 2 (S, G) entries

(\*, 225.1.1.1)

Protocol: pim-dm, Flag: WC EXT

UpTime: 00:09:04

Upstream interface: NULL

Upstream neighbor: NULL

RPF prime neighbor: NULL

Downstream interface(s) information: None

(10.0.3.3, 225.1.1.1)

Protocol: pim-dm, Flag: EXT

UpTime: 00:02:11

Upstream interface: Serial1/0/0

Upstream neighbor: 10.0.12.1

RPF prime neighbor: 10.0.12.1

Downstream interface(s) information: None

(10.0.3.3, 225.1.1.2)

Protocol: pim-dm, Flag:

UpTime: 00:00:08

Upstream interface: Serial1/0/0

Upstream neighbor: 10.0.12.1

RPF prime neighbor: 10.0.12.1

Downstream interface(s) information: None

[R4]display pim routing-table

VPN-Instance: public net

Total 1 (\*, G) entry; 1 (S, G) entry

(\*, 225.1.1.1)

Protocol: pim-dm, Flag: WC

UpTime: 00:08:03

Upstream interface: NULL

Upstream neighbor: NULL

RPF prime neighbor: NULL

Downstream interface(s) information:

Total number of downstreams: 1

1: GigabitEthernet0/0/1

Protocol: static, UpTime: 00:08:03, Expires: never

(10.0.3.3, 225.1.1.1)

Protocol: pim-dm, Flag:

UpTime: 00:02:43

Upstream interface: Serial1/0/0

Upstream neighbor: 10.0.14.1

RPF prime neighbor: 10.0.14.1

Downstream interface(s) information:

Total number of downstreams: 1

1: GigabitEthernet0/0/1

Protocol: pim-dm, UpTime: 00:02:43, Expires: -

默认情况下PIM DM选取接口IP地址较大的路由器作为DR。

[R2]display pim interface

VPN-Instance: public net

Interface State NbrCnt HelloInt DR-Pri DR-Address

GE0/0/0 up 1 30 1 10.0.25.5

S1/0/0 up 1 30 1 10.0.12.2 (local)

在R2上查看接口状态可以看到在与R5连接的接口上，R5是DR。我们可以通过修改接口的优先级来影响DR的选举，该优先级值是一个32bit长度的数值，默认值为1。在下面的例子中，将R2连接到R5的接口的优先级改成100。

[R2]interface GigabitEthernet 0/0/0

[R2-GigabitEthernet0/0/0]pim hello-option dr-priority 100

[R2-GigabitEthernet0/0/0]quit

[R2]display pim interface

VPN-Instance: public net

Interface State NbrCnt HelloInt DR-Pri DR-Address

GE0/0/0 up 1 30 100 10.0.25.2 (local)

S1/0/0 up 1 30 1 10.0.12.2 (local)

可以看到当把路由器接口优先级更改到100以后，R2立刻抢占了DR的位置。

有时为了安全需要，我们希望面向用户侧的接口上不再收发PIM的Hello包，使用**pim silent**可实现该功能。

[R4]interface GigabitEthernet 0/0/1

[R4-GigabitEthernet0/0/1]pim silent

[R4-GigabitEthernet0/0/1]quit

配置完成以后检查PIM Silent已生效。

[R4]display pim interface GigabitEthernet 0/0/1 verbose

VPN-Instance: public net

Interface: GigabitEthernet0/0/1, 10.0.24.4

PIM version: 2

PIM mode: Dense

PIM state: up

PIM DR: 10.0.24.4 (local)

PIM DR Priority (configured): 1

PIM neighbor count: 0

PIM hello interval: 30 s

PIM LAN delay (negotiated): 500 ms

PIM LAN delay (configured): 500 ms

PIM hello override interval (negotiated): 2500 ms

PIM hello override interval (configured): 2500 ms

PIM Silent: enabled

PIM neighbor tracking (negotiated): disabled

PIM neighbor tracking (configured): disabled

PIM join attribute (negotiated): disabled

PIM generation ID: 0X1420A003

PIM require-GenID: disabled

PIM hello hold interval: 105 s

PIM assert hold interval: 180 s

PIM triggered hello delay: 5 s

PIM J/P interval: 60 s

PIM J/P hold interval: 210 s

PIM state-refresh processing: enabled

PIM state-refresh interval: 60 s

PIM graft retry interval: 3 s

PIM state-refresh capability on link: capable

PIM BFD: disabled

PIM dr-switch-delay timer: not configured

Number of routers on link not using DR priority: 0

Number of routers on link not using LAN delay: 0

Number of routers on link not using neighbor tracking: 1

Number of routers on link not using join attribute: 1

ACL of PIM neighbor policy: -

ACL of PIM ASM join policy: -

ACL of PIM SSM join policy: -

ACL of PIM join policy: -

## **附加实验: 思考并验证**

PIM的DM模式适合于用户比较多，比较密集的场景。

思考一下生活中哪些网络应用适合使用PIM DM模式的组播来实现数据转发？它们的特点是什么？

PIM的DM模式在应用在大规模网络上，有哪些劣势？

## **最终设备配置**

<R1>**display current-configuration**

[V200R007C00SPC600]

#

sysname R1

#

interface Serial1/0/0

link-protocol ppp

ip address 10.0.12.1 255.255.255.0

pim dm

#

interface Serial3/0/0

link-protocol ppp

ip address 10.0.14.1 255.255.255.0

pim dm

multicast boundary 225.1.1.2 32

#

ip address 10.0.13.1 255.255.255.0

pim dm

#

interface LoopBack0

ip address 10.0.1.1 255.255.255.255

#

ospf 1 router-id 10.0.1.1

area 0.0.0.0

network 10.0.1.1 0.0.0.0

network 10.0.14.1 0.0.0.0

network 10.0.13.1 0.0.0.0

network 10.0.12.1 0.0.0.0

#

return

<R2>**display current-configuration**

[V200R007C00SPC600]

#

sysname R2

#

interface Serial1/0/0

link-protocol ppp

ip address 10.0.12.2 255.255.255.0

pim dm

#

interface GigabitEthernet0/0/0

ip address 10.0.25.2 255.255.255.0

pim hello-option dr-priority 100

pim dm

#

interface GigabitEthernet0/0/1

ip address 10.0.24.2 255.255.255.0

igmp enable

igmp robust-count 3

igmp timer query 20

igmp static-group 225.1.1.1

#

interface LoopBack0

ip address 10.0.2.2 255.255.255.255

#

ospf 1 router-id 10.0.2.2

area 0.0.0.0

network 10.0.2.2 0.0.0.0

network 10.0.25.2 0.0.0.0

network 10.0.12.2 0.0.0.0

#

ip rpf-route-static 10.0.3.0 24 10.0.12.1

#

return

<R3>**display current-configuration**

[V200R007C00SPC600]

#

sysname R3

#

interface Serial3/0/0

link-protocol ppp

ip address 10.0.35.3 255.255.255.0

pim dm

#

interface GigabitEthernet0/0/2

ip address 10.0.13.3 255.255.255.0

pim dm

#

interface LoopBack0

ip address 10.0.3.3 255.255.255.255

#

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

network 10.0.35.3 0.0.0.0

#

return

<R4>**display current-configuration**

[V200R007C00SPC600]

#

sysname R4

#

interface Serial1/0/0

link-protocol ppp

ip address 10.0.14.4 255.255.255.0

pim dm

#

interface GigabitEthernet0/0/1

ip address 10.0.24.4 255.255.255.0

pim silent

igmp enable

igmp static-group 225.1.1.1

#

interface LoopBack0

ip address 10.0.4.4 255.255.255.255

#

ospf 1 router-id 10.0.4.4

area 0.0.0.0

network 10.0.4.4 0.0.0.0

network 10.0.14.4 0.0.0.0

#

return

<R5>**display current-configuration**

[V200R007C00SPC600]

#

sysname R5

#

interface Serial1/0/0

link-protocol ppp

ip address 10.0.35.5 255.255.255.0

pim dm

#

interface GigabitEthernet0/0/0

ip address 10.0.25.5 255.255.255.0

pim dm

#

interface LoopBack0

ip address 10.0.5.5 255.255.255.255

#

ospf 1 router-id 10.0.5.5

area 0.0.0.0

network 10.0.5.5 0.0.0.0

network 10.0.25.5 0.0.0.0

network 10.0.35.5 0.0.0.0

#

return

实验 5-2 PIM SM及静态RP

学习目的

* 掌握PIM SM协议的配置方法
* 掌握静态RP和RP负载均衡的配置方法

## **拓扑图**

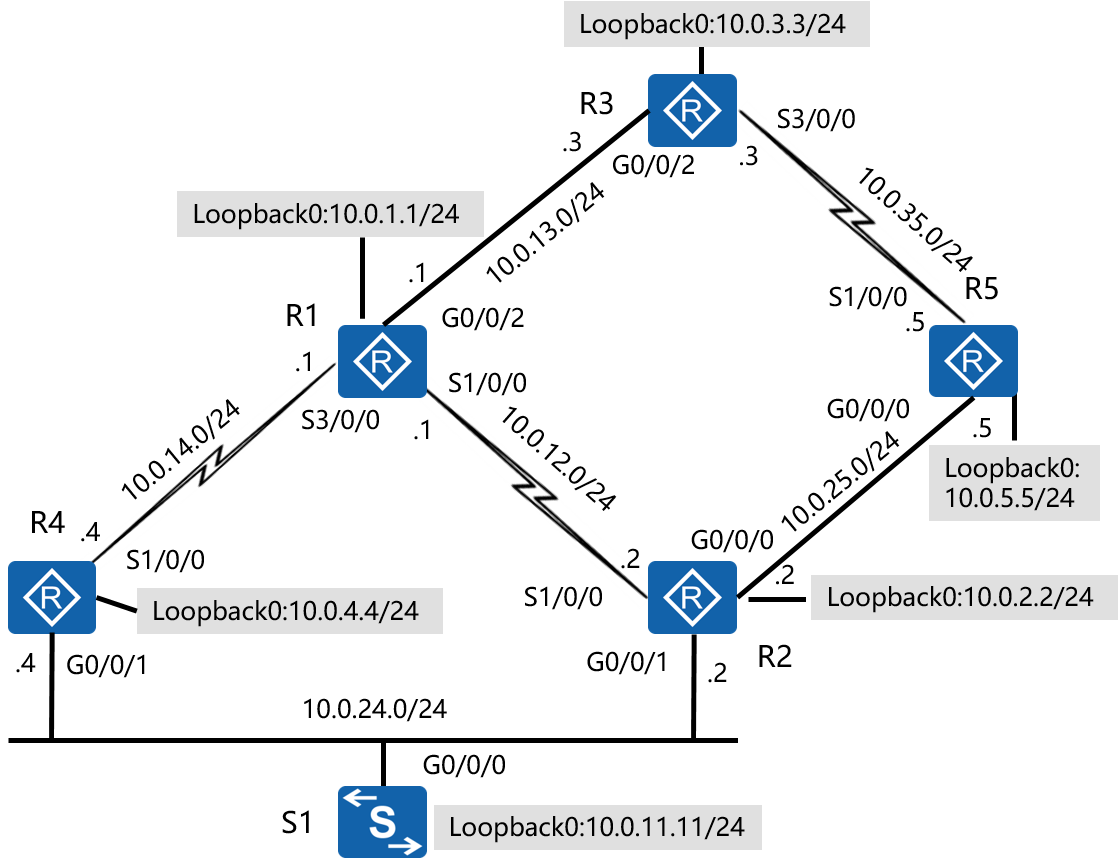


图5-2 PIM SM及动态RP

## **场景**

你是公司的网络管理员。公司以前使用过PIM的DM模式来实现组播路由学习，但是后来发现随着组播应用的发展，组播用户分部越来越广，这时组播质量显示出一定程度的下降。为了提高组播的可靠性、安全性和效率，你决定使用PIM的SM模式来实现组播路由学习。

在PIM的SM模式中，你需要定义RP，作为SM模式的共享树的树根。但是在实际的使用中，只是这样简单的配置是不够的，组播还需要实现RP之间的负载分担。

在实现网络的组播转发之前，你也遇到了一些网络故障，经过一些故障排除步骤，最终网络正常工作了。

学习任务

1. 基础配置与IP编址

S2参与到本次实验（实现R1和R3的互联）。

<Huawei>system-view

Enter system view, return user view with Ctrl+Z.

[Huawei]sysname S2

[S2]vlan 13

[S2-vlan13]quit

[S2]int GigabitEthernet 0/0/1

[S2-GigabitEthernet0/0/1]port link-t access

[S2-GigabitEthernet0/0/1]port default vlan 13

[S2-GigabitEthernet0/0/1]quit

[S2]int GigabitEthernet 0/0/3

[S2-GigabitEthernet0/0/3]port link-t access

[S2-GigabitEthernet0/0/3]port default vlan 13

[S2-GigabitEthernet0/0/3]quit

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。

[R1]interface GigabitEthernet0/0/2

[R1-GigabitEthernet0/0/2]ip address 10.0.13.1 24

[R1-GigabitEthernet0/0/2]quit

[R1]interface Serial 1/0/0

[R1-Serial1/0/0]ip address 10.0.12.1 24

[R1-Serial1/0/0]quit

[R1]interface Serial 3/0/0

[R1-Serial3/0/0]ip address 10.0.14.1 24

[R1-Serial3/0/0]quit

[R1]interface loopback 0

[R1-LoopBack0]ip address 10.0.1.1 24

[R1-LoopBack0]quit

[R2]interface GigabitEthernet0/0/0

[R2-GigabitEthernet0/0/0]ip address 10.0.25.2 24

[R2-GigabitEthernet0/0/0]quit

[R2]interface GigabitEthernet0/0/1

[R2-GigabitEthernet0/0/1]ip address 10.0.24.2 24

[R2-GigabitEthernet0/0/1]quit

[R2]interface Serial 1/0/0

[R2-Serial1/0/0]ip address 10.0.12.2 24

[R2-Serial1/0/0]quit

[R2]interface loopback 0

[R2-LoopBack0]ip address 10.0.2.2 24

[R2-LoopBack0]quit

[R3]interface GigabitEthernet0/0/2

[R3-GigabitEthernet0/0/2]ip address 10.0.13.3 24

[R3-GigabitEthernet0/0/2]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]interface GigabitEthernet0/0/1

[R4-GigabitEthernet0/0/1]ip address 10.0.24.4 24

[R4-GigabitEthernet0/0/1]quit

[R4]interface Serial 1/0/0

[R4-Serial1/0/0]ip address 10.0.14.4 24

[R4-Serial1/0/0]quit

[R4]interface loopback 0

[R4-LoopBack0]ip address 10.0.4.4 24

[R4-LoopBack0]quit

[R5]interface GigabitEthernet0/0/0

[R5-GigabitEthernet0/0/0]ip address 10.0.25.5 24

[R5-GigabitEthernet0/0/0]quit

[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

[S1]interface Vlanif 1

[S1-Vlanif1]ip address 10.0.24.1 24

[S1-Vlanif1]quit

[S1]interface loopback 0

[S1-LoopBack0]ip address 10.0.11.11 24

[S1-LoopBack0]quit

配置完成后，测试直连链路的连通性。

[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=41 ms

--- 10.0.12.2 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 10.0.13.3

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=5 ms

--- 10.0.13.3 ping statistics ---

1 packet(s) transmitted

1 packet(s) received

0.00% packet loss

round-trip min/avg/max = 5/5/5 ms

[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=62 ms

--- 10.0.14.4 ping statistics ---

1 packet(s) transmitted

1 packet(s) received

0.00% packet loss

round-trip min/avg/max = 62/62/62 ms

[R5]ping -c 1 10.0.25.2

PING 10.0.25.2: 56 data bytes, press CTRL\_C to break

Reply from 10.0.25.2: bytes=56 Sequence=1 ttl=255 time=7 ms

--- 10.0.25.2 ping statistics ---

1 packet(s) transmitted

1 packet(s) received

0.00% packet loss

round-trip min/avg/max = 7/7/7 ms

[R5]ping -c 1 10.0.35.3

PING 10.0.35.3: 56 data bytes, press CTRL\_C to break

Reply from 10.0.35.3: bytes=56 Sequence=1 ttl=255 time=37 ms

--- 10.0.35.3 ping statistics ---

1 packet(s) transmitted

1 packet(s) received

0.00% packet loss

round-trip min/avg/max = 37/37/37 ms

[S1]ping -c 1 10.0.24.2

PING 10.0.24.2: 56 data bytes, press CTRL\_C to break

Reply from 10.0.24.2: bytes=56 Sequence=1 ttl=255 time=1 ms

--- 10.0.24.2 ping statistics ---

1 packet(s) transmitted

1 packet(s) received

0.00% packet loss

round-trip min/avg/max = 1/1/1 ms

在R1、R2、R3、R4、 R5和S1上启用OSPF路由协议。实现所有网络互通。

[R1]ospf 1 router-id 10.0.1.1

[R1-ospf-1]area 0

[R1-ospf-1-area-0.0.0.0]network 10.0.14.1 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

[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]quit

[R2]ospf 1 router-id 10.0.2.2

[R2-ospf-1]area 0

[R2-ospf-1-area-0.0.0.0]network 10.0.12.2 0.0.0.0

[R2-ospf-1-area-0.0.0.0]network 10.0.24.2 0.0.0.0

[R2-ospf-1-area-0.0.0.0]network 10.0.25.2 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]quit

[R3]ospf 1 router-id 10.0.3.3

[R3-ospf-1]area 0

[R3-ospf-1-area-0.0.0.0]network 10.0.13.3 0.0.0.0

[R3-ospf-1-area-0.0.0.0]network 10.0.35.3 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]quit

[R4]ospf 1 router-id 10.0.4.4

[R4-ospf-1]area 0

[R4-ospf-1-area-0.0.0.0]network 10.0.14.4 0.0.0.0

[R4-ospf-1-area-0.0.0.0]network 10.0.24.4 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]quit

[R4-ospf-1]quit

[R5]ospf 1 router-id 10.0.5.5

[R5-ospf-1]area 0

[R5-ospf-1-area-0.0.0.0]network 10.0.25.5 0.0.0.0

[R5-ospf-1-area-0.0.0.0]network 10.0.35.5 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]quit

[R5-ospf-1]quit

[S1]ospf 1 router-id 10.0.11.11

[S1-ospf-1]area 0

[S1-ospf-1-area-0.0.0.0]network 10.0.24.1 0.0.0.0

[S1-ospf-1-area-0.0.0.0]network 10.0.11.11 0.0.0.0

[S1-ospf-1-area-0.0.0.0]quit

[S1-ospf-1]quit

配置完成后，稍等片刻，待OSPF邻居关系连接，路由信息交互完成后，测试S1与路由器R3的Loopback 0地址之间的连通性。

[S1]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=253 time=37 ms

--- 10.0.3.3 ping statistics ---

1 packet(s) transmitted

1 packet(s) received

0.00% packet loss

round-trip min/avg/max = 37/37/37 ms

如测试显示，网络工作正常。

1. 配置所有路由器启用PIM SM

启用R1、R2、R3、R4、R5和S1的组播路由功能。

[R1]multicast routing-enable

[R2]multicast routing-enable

[R3]multicast routing-enable

[R4]multicast routing-enable

[R5]multicast routing-enable

[S1]multicast routing-enable

在所有设备的所有接口上配置运行SM模式的PIM。

[R1]interface GigabitEthernet0/0/2

[R1-GigabitEthernet0/0/2]pim sm

[R1-GigabitEthernet0/0/2]quit

[R1]interface Serial 1/0/0

[R1-Serial1/0/0]pim sm

[R1-Serial1/0/0]quit

[R1]interface Serial 3/0/0

[R1-Serial3/0/0]pim sm

[R1-Serial3/0/0]quit

[R1]interface loopback 0

[R1-LoopBack0]pim sm

[R1-LoopBack0]quit

[R2]interface GigabitEthernet0/0/0

[R2-GigabitEthernet0/0/0]pim sm

[R2-GigabitEthernet0/0/0]quit

[R2]interface GigabitEthernet0/0/1

[R2-GigabitEthernet0/0/1]pim sm

[R2-GigabitEthernet0/0/1]quit

[R2]interface Serial 1/0/0

[R2-Serial1/0/0]pim sm

[R2-Serial1/0/0]quit

[R2]interface loopback 0

[R2-LoopBack0]pim sm

[R2-LoopBack0]quit

[R3]interface GigabitEthernet0/0/2

[R3-GigabitEthernet0/0/2]pim sm

[R3-GigabitEthernet0/0/2]quit

[R3]interface Serial 3/0/0

[R3-Serial3/0/0]pim sm

[R3-Serial3/0/0]quit

[R3]interface loopback 0

[R3-LoopBack0]pim sm

[R3-LoopBack0]quit

[R4]interface GigabitEthernet0/0/1

[R4-GigabitEthernet0/0/1]pim sm

[R4-GigabitEthernet0/0/1]quit

[R4]interface Serial 1/0/0

[R4-Serial1/0/0]pim sm

[R4-Serial1/0/0]quit

[R4]interface loopback 0

[R4-LoopBack0]pim sm

[R4-LoopBack0]quit

[R5]interface GigabitEthernet0/0/0

[R5-GigabitEthernet0/0/0]pim sm

[R5-GigabitEthernet0/0/0]quit

[R5]interface Serial 1/0/0

[R5-Serial1/0/0]pim sm

[R5-Serial1/0/0]quit

[R5]interface loopback 0

[R5-LoopBack0]pim sm

[R5-LoopBack0]quit

[S1]interface Vlanif 1

[S1-Vlanif1]pim sm

[S1-Vlanif1]quit

[S1]interface loopback 0

[S1-LoopBack0]pim sm

[S1-LoopBack0]quit

配置完成后，查看R1、R5和S1的PIM邻居学习的情况。

<R1>display pim neighbor

VPN-Instance: public net

Total Number of Neighbors = 3

Neighbor Interface Uptime Expires Dr-Priority BFD-Session

10.0.13.3 GE0/0/2 00:01:25 00:01:20 1 N

10.0.12.2 S1/0/0 00:01:47 00:01:28 1 N

10.0.14.4 S3/0/0 00:00:56 00:01:19 1 N

[R5]display pim neighbor

VPN-Instance: public net

Total Number of Neighbors = 2

Neighbor Interface Uptime Expires Dr-Priority BFD-Session

10.0.25.2 GE0/0/0 00:01:24 00:01:29 1 N

10.0.35.3 S1/0/0 00:01:19 00:01:39 1 N

[S1]display pim neighbor

VPN-Instance: public net

Total Number of Neighbors = 2

Neighbor Interface Uptime Expires Dr-Priority BFD-Session

10.0.24.4 Vlanif1 00:01:24 00:01:28 1 N

10.0.24.2 Vlanif1 00:01:24 00:01:41 1 N

从命令输出结果可以看到，PIM协议已经在网络中正确运行。

1. 静态RP和静态RP负载均衡

通过给网络手动指定静态RP来控制网络中组播数据流。

在所有设备配置R1的S3/0/0接口作为网络中的静态RP。

[R1]pim

[R1-pim]static-rp 10.0.14.1

[R1-pim]quit

[R2]pim

[R2-pim]static-rp 10.0.14.1

[R2-pim]quit

[R3]pim

[R3-pim]static-rp 10.0.14.1

[R3-pim]quit

[R4]pim

[R4-pim]static-rp 10.0.14.1

[R4-pim]quit

[R5]pim

[R5-pim]static-rp 10.0.14.1

[R5-pim]quit

[S1]pim

[S1-pim]static-rp 10.0.14.1

[S1-pim]quit

S1模拟网络中组播用户接入的三层交换机，在S1的Loopback 0接口上开启IGMP功能。

[S1]interface LoopBack 0

[S1-LoopBack0]igmp enable

[S1-LoopBack0]quit

将S1的Loopback 0接口静态加入225.0.0.1组播组，模拟连接有225.0.0.1组播组的用户。

[S1]interface LoopBack 0

[S1-LoopBack0]igmp static-group 225.0.0.1

[S1-LoopBack0]quit

在R1、R4和S1上使用命令**display pim routing-table**查看PIM路由表。

[R1]display pim routing-table

VPN-Instance: public net

Total 1 (\*, G) entry; 0 (S, G) entry

(\*, 225.0.0.1)

RP: 10.0.14.1 (local)

Protocol: pim-sm, Flag: WC

UpTime: 00:02:40

Upstream interface: Register

Upstream neighbor: NULL

RPF prime neighbor: NULL

Downstream interface(s) information:

Total number of downstreams: 1

1: Serial3/0/0

Protocol: pim-sm, UpTime: 00:02:40, Expires: 00:02:50

[R4]display pim routing-table

VPN-Instance: public net

Total 1 (\*, G) entry; 0 (S, G) entry

(\*, 225.0.0.1)

RP: 10.0.14.1

Protocol: pim-sm, Flag: WC

UpTime: 00:01:46

Upstream interface: Serial1/0/0

Upstream neighbor: 10.0.14.1

RPF prime neighbor: 10.0.14.1

Downstream interface(s) information:

Total number of downstreams: 1

1: GigabitEthernet0/0/1

Protocol: pim-sm, UpTime: 00:01:46, Expires: 00:02:43

[S1]display pim routing-table

VPN-Instance: public net

Total 1 (\*, G) entry; 0 (S, G) entry

(\*, 225.0.0.1)

RP: 10.0.14.1

Protocol: pim-sm, Flag: WC

UpTime: 00:01:19

Upstream interface: Vlanif1

Upstream neighbor: 10.0.24.4

RPF prime neighbor: 10.0.24.4

Downstream interface(s) information:

Total number of downstreams: 1

1: LoopBack0

Protocol: static, UpTime: 00:01:19, Expires: -

从命令输出结果可以看到，在指定静态RP的网络中，R1是网络中的RP。S1生成了一条经过R4到达RP路由器R1的组播路径。

创建ACL并应用到静态RP上，定义R1作为RP，服务的组播范围是225.0.0.0/24网段，定义R5作为RP，服务的组播范围是225.0.1.0/24网段。

[R1]acl 2000

[R1-acl-basic-2000]rule permit source 225.0.0.0 0.0.0.255

[R1-acl-basic-2000]quit

[R1]acl 2001

[R1-acl-basic-2001]rule permit source 225.0.1.0 0.0.0.255

[R1-acl-basic-2001]quit

[R1]pim

[R1-pim]static-rp 10.0.14.1 2000

[R1-pim]static-rp 10.0.25.5 2001

[R1-pim]quit

[R2]acl 2000

[R2-acl-basic-2000]rule permit source 225.0.0.0 0.0.0.255

[R2-acl-basic-2000]quit

[R2]acl 2001

[R2-acl-basic-2001]rule permit source 225.0.1.0 0.0.0.255

[R2-acl-basic-2001]quit

[R2]pim

[R2-pim]static-rp 10.0.14.1 2000

[R2-pim]static-rp 10.0.25.5 2001

[R2-pim]quit

[R3]acl 2000

[R3-acl-basic-2000]rule permit source 225.0.0.0 0.0.0.255

[R3-acl-basic-2000]quit

[R3]acl 2001

[R3-acl-basic-2001]rule permit source 225.0.1.0 0.0.0.255

[R3-acl-basic-2001]quit

[R3]pim

[R3-pim]static-rp 10.0.14.1 2000

[R3-pim]static-rp 10.0.25.5 2001

[R3-pim]quit

[R4]acl 2000

[R4-acl-basic-2000]rule permit source 225.0.0.0 0.0.0.255

[R4-acl-basic-2000]quit

[R4]acl 2001

[R4-acl-basic-2001]rule permit source 225.0.1.0 0.0.0.255

[R4-acl-basic-2001]quit

[R4]pim

[R4-pim]static-rp 10.0.14.1 2000

[R4-pim]static-rp 10.0.25.5 2001

[R4-pim]quit

[R5]acl 2000

[R5-acl-basic-2000]rule permit source 225.0.0.0 0.0.0.255

[R5-acl-basic-2000]quit

[R5]acl 2001

[R5-acl-basic-2001]rule permit source 225.0.1.0 0.0.0.255

[R5-acl-basic-2001]quit

[R5]pim

[R5-pim]static-rp 10.0.14.1 2000

[R5-pim]static-rp 10.0.25.5 2001

[R5-pim]quit

[S1]acl 2000

[S1-acl-basic-2000]rule permit source 225.0.0.0 0.0.0.255

[S1-acl-basic-2000]quit

[S1]acl 2001

[S1-acl-basic-2001]rule permit source 225.0.1.0 0.0.0.255

[S1-acl-basic-2001]quit

[S1]pim

[S1-pim]static-rp 10.0.14.1 2000

[S1-pim]static-rp 10.0.25.5 2001

将S1的Loopback 0接口静态加入225.0.1.1组播组，模拟连接有225.0.1.1组播组的用户。

[S1]interface LoopBack 0

[S1-LoopBack0]igmp static-group 225.0.1.1

[S1-LoopBack0]quit

在S1、R2和 R5上使用命令**display pim routing-table**查看PIM路由表。

[R5]display pim routing-table

VPN-Instance: public net

Total 1 (\*, G) entry; 0 (S, G) entry

(\*, 225.0.1.1)

RP: 10.0.25.5 (local)

Protocol: pim-sm, Flag: WC

UpTime: 00:03:13

Upstream interface: Register

Upstream neighbor: NULL

RPF prime neighbor: NULL

Downstream interface(s) information:

Total number of downstreams: 1

1: GigabitEthernet0/0/0

Protocol: pim-sm, UpTime: 00:03:13, Expires: 00:03:17

[R2]display pim routing-table

VPN-Instance: public net

Total 1 (\*, G) entry; 0 (S, G) entry

(\*, 225.0.1.1)

RP: 10.0.25.5

Protocol: pim-sm, Flag: WC

UpTime: 00:03:41

Upstream interface: GigabitEthernet0/0/0

Upstream neighbor: 10.0.25.5

RPF prime neighbor: 10.0.25.5

Downstream interface(s) information:

Total number of downstreams: 1

1: GigabitEthernet0/0/1

Protocol: pim-sm, UpTime: 00:03:41, Expires: 00:02:48

[S1]display pim routing-table

VPN-Instance: public net

Total 2 (\*, G) entries; 0 (S, G) entry

(\*, 225.0.0.1)

RP: 10.0.14.1

Protocol: pim-sm, Flag: WC

UpTime: 00:17:09

Upstream interface: Vlanif1

Upstream neighbor: 10.0.24.4

RPF prime neighbor: 10.0.24.4

Downstream interface(s) information:

Total number of downstreams: 1

1: LoopBack0

Protocol: static, UpTime: 00:17:09, Expires: -

(\*, 225.0.1.1)

RP: 10.0.25.5

Protocol: pim-sm, Flag: WC

UpTime: 00:03:58

Upstream interface: Vlanif1

Upstream neighbor: 10.0.24.2

RPF prime neighbor: 10.0.24.2

Downstream interface(s) information:

Total number of downstreams: 1

1: LoopBack0

Protocol: static, UpTime: 00:03:58, Expires: -

从命令输出结果可以看到，S1针对225.0.0.1和225.0.1.1生成了二条组播路径。225.0.1.1组播路径经过R2到达RP路由器R5。

## **附加实验: 思考并验证**

PIM的SM模式适合于用户比较分散的场景。

思考一下生活中哪些网络应用适合使用PIM SM模式的组播来实现数据转发？它们的特点是什么？

## **最终设备配置**

[R1]**display current-configuration**

[V200R007C00SPC600]

#

sysname R1

#

multicast routing-enable

#

acl number 2000

rule 5 permit source 225.0.0.0 0.0.0.255

acl number 2001

rule 5 permit source 225.0.1.0 0.0.0.255

#

interface Serial1/0/0

link-protocol ppp

ip address 10.0.12.1 255.255.255.0

pim sm

#

interface Serial3/0/0

link-protocol ppp

ip address 10.0.14.1 255.255.255.0

pim sm

#

interface GigabitEthernet0/0/2

ip address 10.0.13.1 255.255.255.0

pim sm

#

interface LoopBack0

ip address 10.0.1.1 255.255.255.0

pim sm

#

ospf 1 router-id 10.0.1.1

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

network 10.0.14.1 0.0.0.0

#

pim

static-rp 10.0.14.1 2000

static-rp 10.0.25.25 2001

#

return

[R2]**display current-configuration**

[V200R007C00SPC600]

#

sysname R2

#

multicast routing-enable

#

acl number 2000

rule 5 permit source 225.0.0.0 0.0.0.255

acl number 2001

rule 5 permit source 225.0.1.0 0.0.0.255

#

interface Serial1/0/0

link-protocol ppp

ip address 10.0.12.2 255.255.255.0

pim sm

#

interface GigabitEthernet0/0/0

ip address 10.0.25.2 255.255.255.0

pim sm

#

interface GigabitEthernet0/0/1

ip address 10.0.24.2 255.255.255.0

pim sm

#

interface LoopBack0

ip address 10.0.2.2 255.255.255.0

pim sm

#

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

network 10.0.24.2 0.0.0.0

network 10.0.25.2 0.0.0.0

#

pim

static-rp 10.0.14.1 2000

static-rp 10.0.25.5 2001

#

return

[R3]**display current-configuration**

[V200R007C00SPC600]

#

sysname R3

#

multicast routing-enable

#

acl number 2000

rule 5 permit source 225.0.0.0 0.0.0.255

acl number 2001

rule 5 permit source 225.0.1.0 0.0.0.255

#

interface Serial3/0/0

link-protocol ppp

ip address 10.0.35.3 255.255.255.0

pim sm

#

interface GigabitEthernet0/0/2

ip address 10.0.13.3 255.255.255.0

pim sm

#

interface GigabitEthernet0/0/3

description VirtualPort

#

interface LoopBack0

ip address 10.0.3.3 255.255.255.0

pim sm

#

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

network 10.0.35.3 0.0.0.0

#

pim

static-rp 10.0.14.1 2000

static-rp 10.0.25.5 2001

#

return

[R4]**display current-configuration**

[V200R007C00SPC600]

#

sysname R4

#

multicast routing-enable

#

acl number 2000

rule 5 permit source 225.0.0.0 0.0.0.255

acl number 2001

rule 5 permit source 225.0.1.0 0.0.0.255

#

interface Serial1/0/0

link-protocol ppp

ip address 10.0.14.4 255.255.255.0

pim sm

#

interface GigabitEthernet0/0/1

ip address 10.0.24.4 255.255.255.0

pim sm

#

interface LoopBack0

ip address 10.0.4.4 255.255.255.0

pim sm

#

ospf 1 router-id 10.0.4.4

area 0.0.0.0

network 10.0.4.4 0.0.0.0

network 10.0.14.4 0.0.0.0

network 10.0.24.4 0.0.0.0

#

pim

static-rp 10.0.14.1 2000

static-rp 10.0.25.5 2001

#

return

[R5]**display current-configuration**

[V200R007C00SPC600]

#

sysname R5

#

multicast routing-enable

#

acl number 2000

rule 5 permit source 225.0.0.0 0.0.0.255

acl number 2001

rule 5 permit source 225.0.1.0 0.0.0.255

#

interface Serial1/0/0

link-protocol ppp

ip address 10.0.35.5 255.255.255.0

pim sm

#

interface GigabitEthernet0/0/0

ip address 10.0.25.5 255.255.255.0

pim sm

#

interface LoopBack0

ip address 10.0.5.5 255.255.255.0

pim sm

#

ospf 1 router-id 10.0.5.5

area 0.0.0.0

network 10.0.5.5 0.0.0.0

network 10.0.25.5 0.0.0.0

network 10.0.35.5 0.0.0.0

#

pim

static-rp 10.0.14.1 2000

static-rp 10.0.25.5 2001

#

return

[S1]**display current-configuration**

!Software Version V200R008C00SPC500

#

sysname S1

#

multicast routing-enable

#

acl number 2000

rule 5 permit source 225.0.0.0 0.0.0.255

acl number 2001

rule 5 permit source 225.0.1.0 0.0.0.255

#

interface Vlanif1

ip address 10.0.24.1 255.255.255.0

pim sm

#

interface LoopBack0

ip address 10.0.11.11 255.255.255.0

pim sm

igmp enable

igmp static-group 225.0.0.1

igmp static-group 225.0.1.1

#

ospf 1 router-id 10.0.11.11

area 0.0.0.0

network 10.0.11.11 0.0.0.0

network 10.0.24.1 0.0.0.0

#

pim

static-rp 10.0.14.1 2000

static-rp 10.0.25.5 2001

#

return

第六章 VLAN特性与配置

实验 6-1 VLAN配置

学习目的

* 掌握Eth-trunk的配置方法

## **拓扑图**

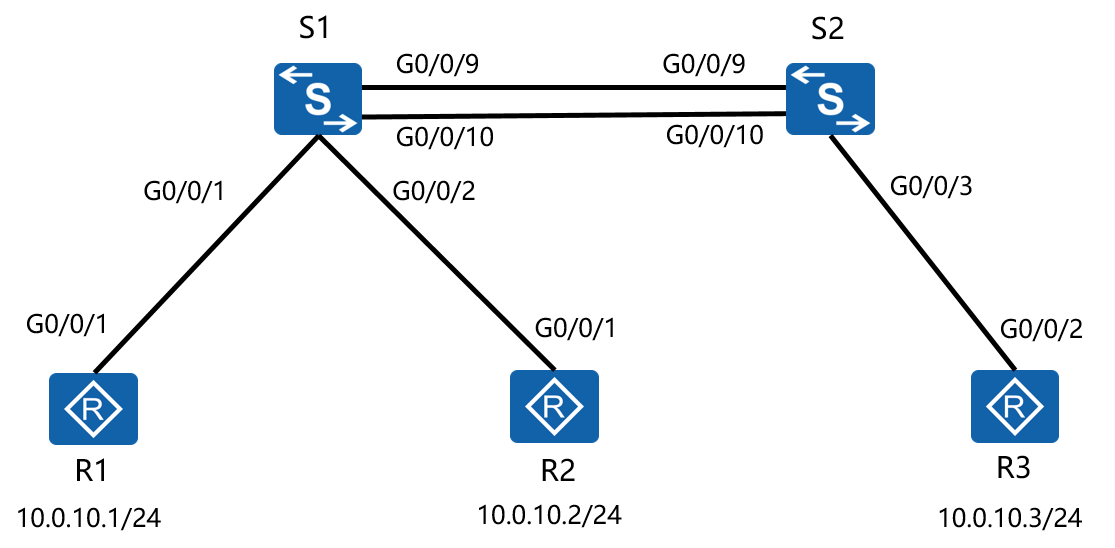


图6-1 VLAN配置

## **场景**

你是公司的网络管理员。现在公司网络是由二台交换机组成的以太网环境。图中路由器模拟网络中的计算机，R3是一台服务器。为了优化这个网络，需要你提升S1和S2相连链路的速度和可靠性。

学习任务

1. 基础配置与IP编址

给所有设备配置IP地址和掩码。

<Huawei>system-view

Enter system view, return user view with Ctrl+Z.

[Huawei]sysname R1

[R1]interface GigabitEthernet 0/0/1

[R1-GigabitEthernet0/0/1]ip address 10.0.10.1 24

[R1-GigabitEthernet0/0/1]quit

<Huawei>system-view

Enter system view, return user view with Ctrl+Z.

[Huawei]sysname R2

[R2]interface GigabitEthernet 0/0/1

[R2-GigabitEthernet0/0/1]ip address 10.0.10.2 24

[R2-GigabitEthernet0/0/1]quit

<Huawei>system-view

Enter system view, return user view with Ctrl+Z.

[Huawei]sysname R3

[R3]interface GigabitEthernet 0/0/2

[R3-GigabitEthernet0/0/2]ip address 10.0.10.3 24

[R3-GigabitEthernet0/0/2]quit

给交换机配置名称。

<Huawei>system-view

Enter system view, return user view with Ctrl+Z.

[Huawei]sysname S1

<Huawei>system-view

Enter system view, return user view with Ctrl+Z.

[Huawei]sysname S2

1. Eth-trunk链路聚合

Eth-trunk可以将二条或多条链路捆绑成一条链路以提升链路带宽和可靠性。将S1和S2的G0/0/9和G0/0/10接口加入到同一个Eth-trunk组可以实现企业需求。

创建Eth-trunk接口。

[S1]interface Eth-Trunk 1

[S1-Eth-Trunk1]

[S2]interface Eth-Trunk 1

[S2-Eth-Trunk1]

配置Eth-trunk的工作模式为LACP模式。

[S1-Eth-Trunk1]mode lacp

[S1-Eth-Trunk1]quit

[S2-Eth-Trunk1]mode lacp

[S2-Eth-Trunk1]quit

将S1和S2的G0/0/9和G0/0/10接口加入到Eth-trunk接口。

[S1]interface GigabitEthernet 0/0/9

[S1-GigabitEthernet0/0/9]eth-trunk 1

[S1-GigabitEthernet0/0/9]quit

[S1]interface GigabitEthernet 0/0/10

[S1-GigabitEthernet0/0/10]eth-trunk 1

[S1-GigabitEthernet0/0/10]quit

[S2]interface GigabitEthernet 0/0/9

[S2-GigabitEthernet0/0/9]eth-trunk 1

[S2-GigabitEthernet0/0/9]quit

[S2]interface GigabitEthernet 0/0/10

[S2-GigabitEthernet0/0/10]eth-trunk 1

[S2-GigabitEthernet0/0/10]quit

使用命令**dispay eth-trunk**查看配置情况。

[S1]display eth-trunk

Eth-Trunk1's state information is:

Local:

LAG ID: 1 WorkingMode: LACP

Preempt Delay: Disabled Hash arithmetic: According to SIP-XOR-DIP

System Priority: 32768 System ID: d0d0-4ba6-aab0

Least Active-linknumber: 1 Max Active-linknumber: 8

Operate status: up Number Of Up Port In Trunk: 2

----------------------------------------------------------------------------

ActorPortName Status PortType PortPri PortNo PortKey PortState Weight

GigabitEthernet0/0/9 Selected 1GE 32768 1 305 10111100 1

GigabitEthernet0/0/10 Selected 1GE 32768 2 305 10111100 1

Partner:

----------------------------------------------------------------------------

ActorPortName SysPri SystemID PortPri PortNo PortKey PortState

GigabitEthernet0/0/9 32768 d0d0-4ba6-ac20 32768 1 305 10111100

GigabitEthernet0/0/10 32768 d0d0-4ba6-ac20 32768 2 305 10111100

输出信息显示，此时链路运行模式为LACP模式，并且最大活动接口数阈值是8条链路。同时G0/0/9和G0/0/10接口都处于活动状态。

使用命令更改活动接口数阈值。

[S1]interface Eth-Trunk 1

[S1-Eth-Trunk1]max active-linknumber 1

[S1-Eth-Trunk1]quit

[S2]interface Eth-Trunk 1

[S2-Eth-Trunk1]max active-linknumber 1

[S2-Eth-Trunk1]quit

查看Eth-trunk链路配置情况。

[S1]display eth-trunk 1

Eth-Trunk1's state information is:

Local:

LAG ID: 1 WorkingMode: LACP

Preempt Delay: Disabled Hash arithmetic: According to SIP-XOR-DIP

System Priority: 32768 System ID: d0d0-4ba6-aab0

Least Active-linknumber: 1 Max Active-linknumber: 1

Operate status: up Number Of Up Port In Trunk: 1

----------------------------------------------------------------------------

ActorPortName Status PortType PortPri PortNo PortKey PortState Weight

GigabitEthernet0/0/9 Selected 1GE 32768 1 305 10111100 1

GigabitEthernet0/0/10 Unselect 1GE 32768 2 305 10100000 1

Partner:

----------------------------------------------------------------------------

ActorPortName SysPri SystemID PortPri PortNo PortKey PortState

GigabitEthernet0/0/9 32768 d0d0-4ba6-ac20 32768 1 305 10111100

GigabitEthernet0/0/10 32768 d0d0-4ba6-ac20 32768 2 305 10100000

从输出信息可以看到，G0/0/10接口状态改变为Unselect。实现了Eth-trunk聚合链路下一条链路传输数据，另一条链路备份的功能，提升了网络可靠性。

通过关闭S1的G0/0/9接口验证备份链路功能。

[S1]interface GigabitEthernet 0/0/9

[S1-GigabitEthernet0/0/9]shutdown

[S1-GigabitEthernet0/0/9]quit

查看Eth-trunk链路信息。

[S1]display eth-trunk 1

Eth-Trunk1's state information is:

Local:

LAG ID: 1 WorkingMode: LACP

Preempt Delay: Disabled Hash arithmetic: According to SIP-XOR-DIP

System Priority: 32768 System ID: d0d0-4ba6-aab0

Least Active-linknumber: 1 Max Active-linknumber: 1

Operate status: up Number Of Up Port In Trunk: 1

----------------------------------------------------------------------------

ActorPortName Status PortType PortPri PortNo PortKey PortState Weight

GigabitEthernet0/0/9 Unselect 1GE 32768 1 305 10100010 1

GigabitEthernet0/0/10 Selected 1GE 32768 2 305 10111100 1

Partner:

----------------------------------------------------------------------------

ActorPortName SysPri SystemID PortPri PortNo PortKey PortState

GigabitEthernet0/0/9 0 0000-0000-0000 0 0 0 10100011

GigabitEthernet0/0/10 32768 d0d0-4ba6-ac20 32768 2 305 10111100

从输出信息看到Eth-trunk链路中G0/0/9已经变为Unselect状态，G0/0/10由Unselect状态自动转换为Selected状态继续传输数据。由此可知，实现了链路备份功能。

## **最终设备配置**

[S1]**display current-configuration**

!Software Version V200R008C00SPC500

#

sysname S1

#

interface Eth-Trunk1

mode lacp

max active-linknumber 1

#

interface GigabitEthernet0/0/9

shutdown

eth-trunk 1

#

interface GigabitEthernet0/0/10

eth-trunk 1

#

return

[S2]**display current-configuration**

!Software Version V200R008C00SPC500

#

sysname S2

#

interface Eth-Trunk1

mode lacp

max active-linknumber 1

#

interface GigabitEthernet0/0/9

shutdown

eth-trunk 1

#

interface GigabitEthernet0/0/10

eth-trunk 1

#

Return

实验 6-2 MUX VLAN (选做)

学习目的

* 掌握MUX VLAN的配置方法

## **拓扑图**

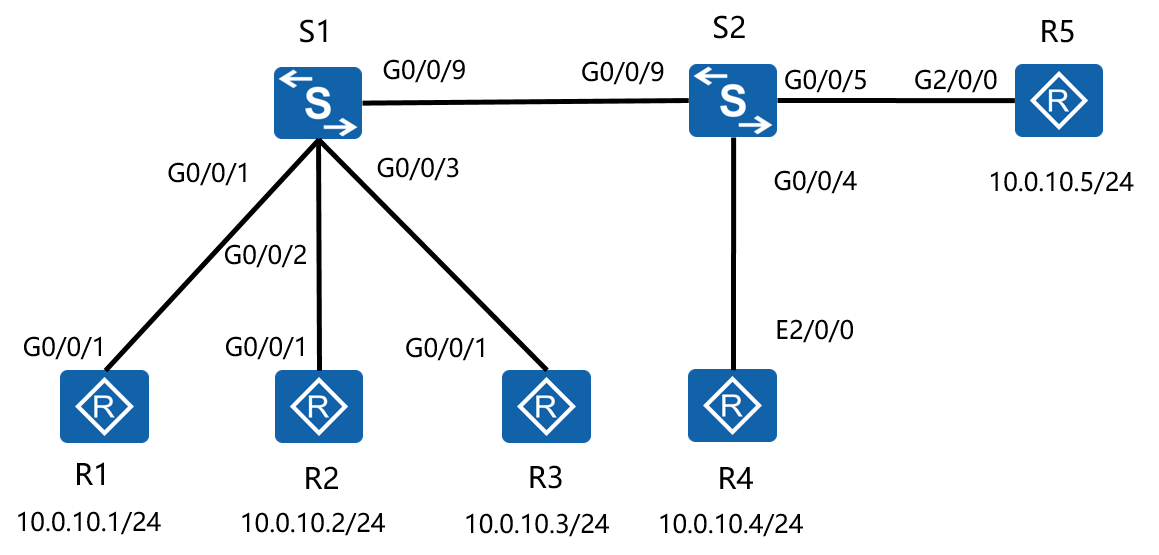


图6-2 MUX VLAN配置

## **场景**

你是公司的网络管理员。现在公司网络是由二台交换机组成的以太网环境。图中路由器代表网络中的计算机。为了优化这个网络，需要你实现广播域的互相隔离。R1和R2处于相同的VLAN中，R3和R4分别处另一个VLAN中。公司策略需要所有PC均可以访问R5，R3和R4除了不能与R1、R2通信外也不能互相访问。

学习任务

1. 基础配置与IP编址

给所有设备配置IP地址和掩码。

<Huawei>system-view

Enter system view, return user view with Ctrl+Z.

[Huawei]sysname R1

[R1]interface g0/0/1

[R1-GigabitEthernet0/0/1]ip address 10.0.10.1 24

[R1-GigabitEthernet0/0/1]quit

<Huawei>system-view

Enter system view, return user view with Ctrl+Z.

[Huawei]sysname R2

[R2]interface g0/0/1

[R2-GigabitEthernet0/0/1]ip address 10.0.10.2 24

[R2-GigabitEthernet0/0/1]quit

<Huawei>system-view

Enter system view, return user view with Ctrl+Z.

[Huawei]sysname R3

[R3]interface g0/0/1

[R3-GigabitEthernet0/0/1]ip address 10.0.10.3 24

[R3-GigabitEthernet0/0/1]quit

<Huawei>system-view

Enter system view, return user view with Ctrl+Z.

[Huawei]sysname R4

[R4]interface Ethernet2/0/0

[R4-Ethernet2/0/0]ip address 10.0.10.4 24

[R4-GigabitEthernet2/0/0]quit

<Huawei>system-view

Enter system view, return user view with Ctrl+Z.

[Huawei]sysname R5

[R5]interface Ethernet2/0/0

[R5-Ethernet2/0/0]ip address 10.0.10.5 24

[R1-GigabitEthernet0/0/1]quit

<Huawei>system-view

Enter system view, return user view with Ctrl+Z.

[Huawei]sysname S1

[S1]

<Huawei>system-view

Enter system view, return user view with Ctrl+Z.

[Huawei]sysname S2

[S2]

在R1上测试与R2、R3、R4和R5的连通性。

[R1]ping -c 1 10.0.10.2

PING 10.0.10.2: 56 data bytes, press CTRL\_C to break

Reply from 10.0.10.2: bytes=56 Sequence=1 ttl=255 time=14 ms

--- 10.0.10.2 ping statistics ---

1 packet(s) transmitted

1 packet(s) received

0.00% packet loss

round-trip min/avg/max = 14/14/14 ms

[R1]ping -c 1 10.0.10.3

PING 10.0.10.3: 56 data bytes, press CTRL\_C to break

Reply from 10.0.10.3: bytes=56 Sequence=1 ttl=255 time=5 ms

--- 10.0.10.3 ping statistics ---

1 packet(s) transmitted

1 packet(s) received

0.00% packet loss

round-trip min/avg/max = 5/5/5 ms

[R1]ping -c 1 10.0.10.4

PING 10.0.10.4: 56 data bytes, press CTRL\_C to break

Reply from 10.0.10.4: bytes=56 Sequence=1 ttl=255 time=15 ms

--- 10.0.10.4 ping statistics ---

1 packet(s) transmitted

1 packet(s) received

0.00% packet loss

round-trip min/avg/max = 15/15/15 ms

[R1]ping -c 1 10.0.10.5

PING 10.0.10.5: 56 data bytes, press CTRL\_C to break

Reply from 10.0.10.5: bytes=56 Sequence=1 ttl=255 time=6 ms

--- 10.0.10.5 ping statistics ---

1 packet(s) transmitted

1 packet(s) received

0.00% packet loss

round-trip min/avg/max = 6/6/6 ms

1. MUX VLAN

MUX VLAN可以实现处于相同网段的设备划入不同VLAN后，虽然二层通信是隔离的，但是还可以和同一个指定VLAN通信。并且还能实现禁止相同VLAN内不同设备之间的通信。

将VLAN 100配置为MUX VLAN的主VLAN，VLAN 10和20配置为从VLAN。

通过配置各PC与交换机相连接口的类型实现所有PC均可和R4通信，R3和R4不能和其他VLAN通信的同时也不能互相通信。

配置VLAN 100为主VLAN并添加从VLAN配置。

[S1]vlan batch 10 20 100

[S1]vlan 100

[S1-vlan100]mux-vlan

[S1-vlan100]subordinate group 10

[S1-vlan100]subordinate separate 20

[S1-vlan100]quit

[S2]vlan batch 10 20 100

[S2]vlan 100

[S2-vlan100]mux-vlan

[S2-vlan100]subordinate group 10

[S2-vlan100]subordinate separate 20

[S2-vlan100]quit

将R5与S2连接的G0/0/5接口加入VLAN 100并开启MUX VLAN功能。

[S2]interface GigabitEthernet 0/0/5

[S2-GigabitEthernet0/0/5]port link-type access

[S2-GigabitEthernet0/0/5]port default vlan 100

[S2-GigabitEthernet0/0/5]port mux-vlan enable vlan 100

[S2-GigabitEthernet0/0/5]quit

将R1与S1连接的G0/0/1和R2与S1连接的G0/0/2接口加入VLAN 10并开启MUX VLAN功能。

[S1]interface GigabitEthernet 0/0/1

[S1-GigabitEthernet0/0/1]port link-type access

[S1-GigabitEthernet0/0/1]port default vlan 10

[S1-GigabitEthernet0/0/1]port mux-vlan enable vlan 10

[S1-GigabitEthernet0/0/1]quit

[S1]interface GigabitEthernet 0/0/2

[S1-GigabitEthernet0/0/2]port link-type access

[S1-GigabitEthernet0/0/2]port default vlan 10

[S1-GigabitEthernet0/0/2]port mux-vlan enable vlan 10

[S1-GigabitEthernet0/0/2]quit

将R3与S1的G0/0/3和R4与S2的G0/0/4接口加入VLAN 20并开启MUX VLAN功能。

[S1]interface GigabitEthernet 0/0/3

[S1-GigabitEthernet0/0/3]port link-type access

[S1-GigabitEthernet0/0/3]port default vlan 20

[S1-GigabitEthernet0/0/3]port mux-vlan enable vlan 20

[S1-GigabitEthernet0/0/3]quit

[S2]interface GigabitEthernet 0/0/4

[S2-GigabitEthernet0/0/4]port link-type access

[S2-GigabitEthernet0/0/4]port default vlan 20

[S2-GigabitEthernet0/0/4]port mux-vlan enable vlan 20

[S2-GigabitEthernet0/0/4]quit

使用命令**display mux-vlan**查看所有MUX VLAN信息。

[S1]display mux-vlan

Principal Subordinate Type Interface

----------------------------------------------------------------------------

100 - principal

100 20 separate GE0/0/3

100 10 group GE0/0/1 GE0/0/2

----------------------------------------------------------------------------

[S2]display mux-vlan

Principal Subordinate Type Interface

----------------------------------------------------------------------------100 - principal GE0/0/5

100 20 separate GE0/0/4

100 10 group

----------------------------------------------------------------------------

使用**ping**命令测试R1与R2、R3、R4、R5的连通性。

[R1]ping -c 1 10.0.10.2

PING 10.0.10.2: 56 data bytes, press CTRL\_C to break

Reply from 10.0.10.2: bytes=56 Sequence=1 ttl=255 time=3 ms

--- 10.0.10.2 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 10.0.10.3

PING 10.0.10.3: 56 data bytes, press CTRL\_C to break

Request time out

--- 10.0.10.3 ping statistics ---

1 packet(s) transmitted

0 packet(s) received

100.00% packet loss

[R1]ping -c 1 10.0.10.4

PING 10.0.10.4: 56 data bytes, press CTRL\_C to break

Request time out

--- 10.0.10.4 ping statistics ---

1 packet(s) transmitted

0 packet(s) received

100.00% packet loss

[R1]ping -c 1 10.0.10.5

PING 10.0.10.5: 56 data bytes, press CTRL\_C to break

Reply from 10.0.10.5: bytes=56 Sequence=1 ttl=255 time=3 ms

--- 10.0.10.5 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**ping**命令测试R3与R2、R4、R5的连通性。

[R3]ping -c 1 10.0.10.2

PING 10.0.10.2: 56 data bytes, press CTRL\_C to break

Request time out

--- 10.0.10.2 ping statistics ---

1 packet(s) transmitted

0 packet(s) received

100.00% packet loss

[R3]ping -c 1 10.0.10.4

PING 10.0.10.4: 56 data bytes, press CTRL\_C to break

Request time out

--- 10.0.10.4 ping statistics ---

1 packet(s) transmitted

0 packet(s) received

100.00% packet loss

[R3]ping -c 1 10.0.10.5

PING 10.0.10.5: 56 data bytes, press CTRL\_C to break

Reply from 10.0.10.5: bytes=56 Sequence=1 ttl=255 time=3 ms

--- 10.0.10.5 ping statistics ---

1 packet(s) transmitted

1 packet(s) received

0.00% packet loss

round-trip min/avg/max = 3/3/3 ms

从**ping**命令输出结果可知。 MUX VLAN中VLAN 10内部的R1和R2除了能够和R5通信外还能互相通信。VLAN 20内部的R3和R4仅仅能够和R5通信。

## **附加实验: 思考并验证**

属于二个不同的MUX VLAN之间的用户，互相通信是否能实现？

## **最终设备配置**

[S1]**display current-configuration**

!Software Version V200R008C00SPC500

#

sysname S1

#

vlan batch 10 20 100

#

vlan 100

mux-vlan

subordinate separate 20

subordinate group 10

#

interface GigabitEthernet0/0/1

port link-type access

port default vlan 10

port mux-vlan enable vlan 10

#

interface GigabitEthernet0/0/2

port link-type access

port default vlan 10

port mux-vlan enable vlan 10

#

interface GigabitEthernet0/0/3

port link-type access

port default vlan 20

port mux-vlan enable vlan 20

#

return

[S2]**display current-configuration**

!Software Version V200R008C00SPC500

#

sysname SW2

#

vlan batch 10 20 100

#

vlan 100

mux-vlan

subordinate separate 20

subordinate group 10

#

interface GigabitEthernet0/0/4

port link-type access

port default vlan 20

port mux-vlan enable vlan 20

#

interface GigabitEthernet0/0/5

port link-type access

port default vlan 100

port mux-vlan enable vlan 100

#

return

实验 6-3 VLAN间通信

学习目的

* 掌握多臂路由的配置方法
* 掌握单臂路由的配置方法
* 掌握VLAN间通信的配置方法
* 掌握VLAN聚合的配置方法

## **拓扑图**

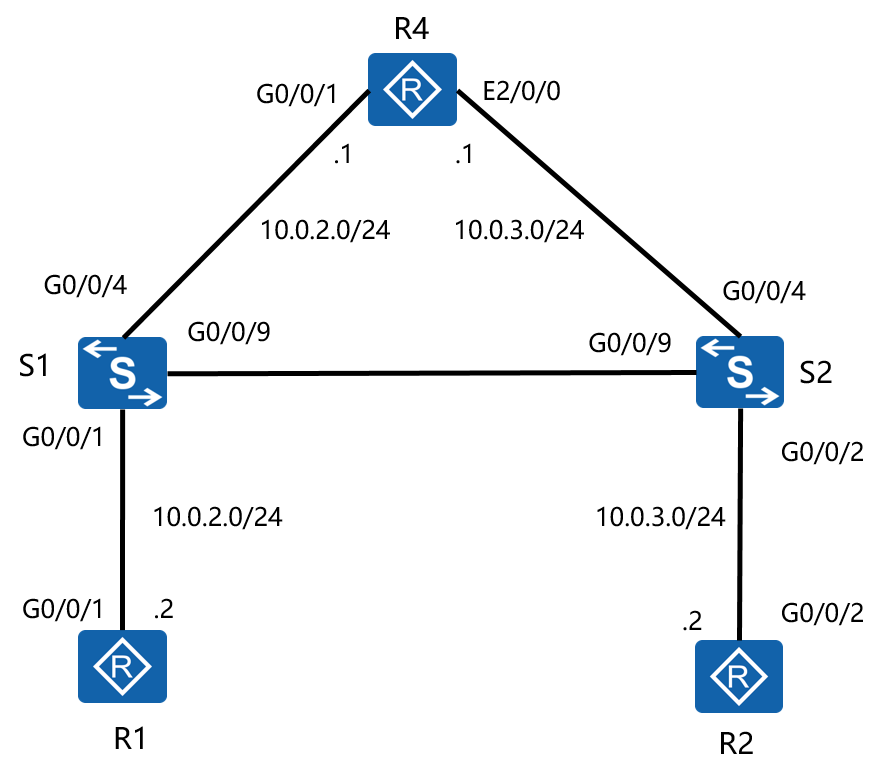


图6-3 VLAN间通信

## **场景**

你是公司的网络管理员。现在公司网络是由二台交换机和一台路由器组成的以太网环境。图中R1和R2代表公司不同部门的PC，分别加入了二个不同的VLAN。现在需要你实现R1和R2之间的通信。公司最初使用的是多臂路由，后来为了节省成本使用单臂路由。

再后来，因为网络架构的变化，流量更多是在VLAN间传输，所以采用了多层交换。最后，因为为了方便网络管理采用VLAN聚合的技术。

学习任务

1. 基础配置与IP编址

给所有设备配置IP地址和掩码。

<huawei>system-view

Enter system view, return user view with Ctrl+Z.

[huawei]sysname R1

[R1]interface GigabitEthernet 0/0/1

[R1-GigabitEthernet0/0/1]ip address 10.0.2.2 24

[R1-GigabitEthernet0/0/1]quit

<huawei>system-view

Enter system view, return user view with Ctrl+Z.

[huawei]sysname R2

[R2]interface GigabitEthernet 0/0/2

[R2-GigabitEthernet0/0/2]ip address 10.0.3.2 24

[R2-GigabitEthernet0/0/2]quit

<Huawei>system-view

Enter system view, return user view with Ctrl+Z.

[Huawei]sysname S1

<Huawei>system-view

Enter system view, return user view with Ctrl+Z.

[Huawei]sysname S2

<huawei>system-view

Enter system view, return user view with Ctrl+Z.

[huawei]sysname R4

[R4]interface GigabitEthernet 0/0/1

[R4-GigabitEthernet0/0/1]ip address 10.0.2.1 24

[R4-GigabitEthernet0/0/1]quit

[R4]interface Ethernet2/0/0

[R4-Ethernet2/0/0]ip address 10.0.3.1 24

[R4-Ethernet2/0/0]quit

使用**ping**命令测试R1与R4接口G0/0/1的地址的连通性。

[R1]ping -c 1 10.0.2.1

PING 10.0.2.1: 56 data bytes, press CTRL\_C to break

Reply from 10.0.2.1: bytes=56 Sequence=1 ttl=255 time=4 ms

--- 10.0.2.1 ping statistics ---

1 packet(s) transmitted

1 packet(s) received

0.00% packet loss

round-trip min/avg/max = 4/4/4 ms

使用**ping**命令测试R2和R4直连接口的连通性。

[R2]ping -c 1 10.0.3.1

PING 10.0.3.1: 56 data bytes, press CTRL\_C to break

Reply from 10.0.3.1: bytes=56 Sequence=1 ttl=255 time=3 ms

--- 10.0.3.1 ping statistics ---

1 packet(s) transmitted

1 packet(s) received

0.00% packet loss

round-trip min/avg/max = 3/3/3 ms

1. 多臂路由

R1和R2分别处于不同的VLAN中。

R1的网关使用R4的G0/0/1接口地址，R2的网关使用R4的E2/0/0接口地址。

由R4的多个接口提供VLAN间通信的服务就叫做多臂路由。

在交换机S1和S2上创建VLAN2和VLAN3。

[S1]vlan batch 2 3

Info: This operation may take a few seconds. Please wait for a moment...done.

[S2]vlan batch 2 3

Info: This operation may take a few seconds. Please wait for a moment...done.

将R1加入VLAN2，R2加入VLAN3，R4的G0/0/1加入VLAN2，E2/0/0加入VLAN3。

[S1]interface GigabitEthernet 0/0/1

[S1-GigabitEthernet0/0/1]port link-type access

[S1-GigabitEthernet0/0/1]port default vlan 2

[S1-GigabitEthernet0/0/1]quit

[S1]interface GigabitEthernet 0/0/4

[S1-GigabitEthernet0/0/4]port link-type access

[S1-GigabitEthernet0/0/4]port default vlan 2

[S1-GigabitEthernet0/0/4]quit

[S2]interface GigabitEthernet 0/0/2

[S2-GigabitEthernet0/0/2]port link-type access

[S2-GigabitEthernet0/0/2]port default vlan 3

[S2-GigabitEthernet0/0/2]quit

[S2]interface GigabitEthernet 0/0/4

[S2-GigabitEthernet0/0/4]port link-type access

[S2-GigabitEthernet0/0/4]port default vlan 3

[S2-GigabitEthernet0/0/4]quit

在R1和R2上配置网关，分别使用所在VLAN的R4接口地址。

[R1]ip route-static 0.0.0.0 0 10.0.2.1

[R2]ip route-static 0.0.0.0 0 10.0.3.1

使用命令**display vlan**查看并确认配置。

[S1]display vlan 2

----------------------------------------------------------------------------

U: Up; D: Down; TG: Tagged; UT: Untagged;

MP: Vlan-mapping; ST: Vlan-stacking;

#: ProtocolTransparent-vlan; \*: Management-vlan;

----------------------------------------------------------------------------

VID Type Ports

----------------------------------------------------------------------------

2 common UT:GE0/0/1(U) GE0/0/4(U)

TG:GE0/0/9(U) GE0/0/10(U)

VID Status Property MAC-LRN Statistics Description

----------------------------------------------------------------------------

2 enable default enable disable VLAN 0002

[S2]display vlan 3

----------------------------------------------------------------------------

U: Up; D: Down; TG: Tagged; UT: Untagged;

MP: Vlan-mapping; ST: Vlan-stacking;

#: ProtocolTransparent-vlan; \*: Management-vlan;

----------------------------------------------------------------------------

VID Type Ports

----------------------------------------------------------------------------

3 common UT:GE0/0/2(U) GE0/0/4(U)

TG:GE0/0/9(U) GE0/0/10(U)

VID Status Property MAC-LRN Statistics Description

----------------------------------------------------------------------------

3 enable default enable disable VLAN 0003

测试R1和R2之间的连通性。

[R1]ping -c 1 10.0.3.2

PING 10.0.3.2: 56 data bytes, press CTRL\_C to break

Reply from 10.0.3.2: bytes=56 Sequence=1 ttl=254 time=3 ms

--- 10.0.3.2 ping statistics ---

1 packet(s) transmitted

1 packet(s) received

0.00% packet loss

round-trip min/avg/max = 3/3/3 ms

[R2]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=254 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

1. 单臂路由

在R4的一个物理接口上创建二个子接口，VLAN间的通讯通过对应的子接口完成。

这种方法叫做单臂路由。

关闭S2的G0/0/4接口。

[S2]interface GigabitEthernet 0/0/4

[S2-GigabitEthernet0/0/4]shutdown

[S2-GigabitEthernet0/0/4]quit

将S1和S2的G0/0/9接口加入VLAN 3。

[S2]interface GigabitEthernet 0/0/9

[S2-GigabitEthernet0/0/9]port link-type access

[S2-GigabitEthernet0/0/9]port default vlan 3

[S2-GigabitEthernet0/0/9]quit

[S1]interface GigabitEthernet 0/0/9

[S1-GigabitEthernet0/0/9]port link-type access

[S1-GigabitEthernet0/0/9]port default vlan 3

[S1-GigabitEthernet0/0/9]quit

将S1的G0/0/4接口模式改为Trunk模式，并允许VLAN2和VLAN3通过。

[S1]interface GigabitEthernet 0/0/4

[S1-GigabitEthernet0/0/4]port default vlan 1

[S1-GigabitEthernet0/0/4]port link-type trunk

[S1-GigabitEthernet0/0/4]port trunk allow-pass vlan 2 3

[S1-GigabitEthernet0/0/4]quit

在R4上为G0/0/1接口创建两个子接口。同时子接口上配置IP地址，并封装相应vid。

[R4]inter GigabitEthernet 0/0/1.2

[R4-GigabitEthernet0/0/1.2]dot1q termination vid 2

[R4-GigabitEthernet0/0/1.2]arp broadcast enable

[R4-GigabitEthernet0/0/1.2]ip address 10.0.20.1 24

[R4-GigabitEthernet0/0/1.2]quit

[R4]interface GigabitEthernet 0/0/1.3

[R4-GigabitEthernet0/0/1.3]dot1q termination vid 3

[R4-GigabitEthernet0/0/1.3]arp broadcast enable

[R4-GigabitEthernet0/0/1.3]ip address 10.0.30.1 24

[R4-GigabitEthernet0/0/1.3]quit

使用**display ip interface brief**命令查看R4上子接口配置信息。

[R4]display ip interface brief

\*down: administratively down

^down: standby

(l): loopback

(s): spoofing

(E): E-Trunk down

The number of interface that is UP in Physical is 7

The number of interface that is DOWN in Physical is 6

The number of interface that is UP in Protocol is 5

The number of interface that is DOWN in Protocol is 8

Interface IP Address/Mask Physical Protocol

Cellular0/0/0 unassigned down down

Cellular0/0/1 unassigned down down

Ethernet2/0/0 10.0.3.1/24 down down

Ethernet2/0/1 unassigned down down

GigabitEthernet0/0/0 unassigned up down

GigabitEthernet0/0/1 10.0.2.1/24 up up

GigabitEthernet0/0/1.2 10.0.20.1/24 up up

GigabitEthernet0/0/1.3 10.0.30.1/24 up up

GigabitEthernet0/0/2 unassigned down down

GigabitEthernet0/0/3 unassigned up down

NULL0 unassigned up up(s)

Serial1/0/0 unassigned up up

Serial1/0/1 unassigned down down

更改R1和R2的IP地址和网关。

[R1]interface GigabitEthernet 0/0/1

[R1-GigabitEthernet0/0/1]ip address 10.0.20.2 24

[R1-GigabitEthernet0/0/1]quit

[R1]undo ip route-static 0.0.0.0 0 10.0.2.1

[R1]ip route-static 0.0.0.0 0 10.0.20.1

[R2]interface GigabitEthernet 0/0/2

[R2-GigabitEthernet0/0/2]ip address 10.0.30.2 24

[R2-GigabitEthernet0/0/2]quit

[R2]undo ip route-static 0.0.0.0 0 10.0.3.1

[R2]ip route-static 0.0.0.0 0 10.0.30.1

测试R1和R2之间的连通性。

[R1]ping -c 1 10.0.30.2

PING 10.0.30.2: 56 data bytes, press CTRL\_C to break

Reply from 10.0.30.2: bytes=56 Sequence=1 ttl=254 time=3 ms

--- 10.0.30.2 ping statistics ---

1 packet(s) transmitted

1 packet(s) received

0.00% packet loss

round-trip min/avg/max = 3/3/3 ms

从**ping**命令的输出结果可知，VLAN 2的计算机和VLAN 3的计算机成功通信。

这种方案相对于多臂路由方案可以节省企业购买路由器接口的资金。

但相对的，单臂路由由于所有数据都在同一个接口上传输，随着VLAN数量的增加将会增大这条链路的带宽压力。同时这条链路也成为了企业网络的单点故障，一旦出现问题则整个网络都无法通信。

1. 三层交换

三层交换指的是不需要路由器帮助，每个VLAN都有一个Vlanif接口充当路由器接口的角色来实现不同VLAN间通信的方法。

关闭S1的G0/0/4接口。

[S1]interface GigabitEthernet 0/0/4

[S1-GigabitEthernet0/0/4]shutdown

[S1-GigabitEthernet0/0/4]quit

更改S1的G0/0/9接口和S2的G0/0/9接口的模式为Trunk模式，允许VLAN2和VLAN3通过。

[S1]interface GigabitEthernet 0/0/9

[S1-GigabitEthernet0/0/9]port default vlan 1

[S1-GigabitEthernet0/0/9]port link-type trunk

[S1-GigabitEthernet0/0/9]port trunk allow-pass vlan 2 3

[S1-GigabitEthernet0/0/9]quit

[S2]interface GigabitEthernet 0/0/9

[S2-GigabitEthernet0/0/9]port default vlan 1

[S2-GigabitEthernet0/0/9]port link-type trunk

[S2-GigabitEthernet0/0/9]port trunk allow-pass vlan 2 3

[S2-GigabitEthernet0/0/9]quit

在S1上创建Vlanif 2接口和Vlanif 3接口，并配置IP地址。

[S1]interface Vlanif 2

[S1-Vlanif2]ip address 10.0.20.1 24

[S1-Vlanif2]quit

[S1]inter Vlanif 3

[S1-Vlanif3]ip address 10.0.30.1 24

[S1-Vlanif3]quit

测试R1和R2之间的连通性。

[R1]ping -c 1 10.0.30.2

PING 10.0.30.2: 56 data bytes, press CTRL\_C to break

Reply from 10.0.30.2: bytes=56 Sequence=1 ttl=254 time=2 ms

--- 10.0.30.2 ping statistics ---

1 packet(s) transmitted

1 packet(s) received

0.00% packet loss

round-trip min/avg/max = 2/2/2 ms

从**ping**命令的输出结果可知，VLAN2 和VLAN 3的计算机通过交换机S1的二个Vlanif接口实现了三层数据通信。

相比单臂路由方案，三层交换更具有扩展性，即使VLAN增加也不会对其性能造成很大影响。

在VLAN间通信占企业大部分流量的网络中能够很好的承担服务压力。

1. VLAN聚合

VLAN聚合和三层交换类似，都可以实现交换机上不同VLAN之间的通信。相比三层交换的方案它能将所有VLAN都放置在同一个网段中，达到减少IP网段使用和统一网关配置的效果。

在S1和S2上创建VLAN 10、20、100。

[S1]vlan batch 10 20 100

Info: This operation may take a few seconds. Please wait for a moment...done.

[S2]vlan batch 10 20 100

Info: This operation may take a few seconds. Please wait for a moment...done.

配置S1和S2的G0/0/9接口允许VLAN10、20通过。

[S1]interface GigabitEthernet 0/0/9

[S1-GigabitEthernet0/0/9]port trunk allow-pass vlan 10 20

[S1-GigabitEthernet0/0/9]quit

[S2]interface GigabitEthernet 0/0/9

[S2-GigabitEthernet0/0/9]port trunk allow-pass vlan 10 20

[S2-GigabitEthernet0/0/9]quit

将S1的G0/0/1接口和S2的G0/0/2接口分别加入VLAN 10和VLAN 20。

[S1]interface GigabitEthernet 0/0/1

[S1-GigabitEthernet0/0/1]port default vlan 10

[S1-GigabitEthernet0/0/1]quit

[S2]interface GigabitEthernet 0/0/2

[S2-GigabitEthernet0/0/1]port default vlan 20

[S2-GigabitEthernet0/0/1]quit

将VLAN100配置为Super-VLAN，并将VLAN 10和VLAN 20作为Sub-VLAN加入VLAN 100。

[S1]vlan 100

[S1-vlan100]aggregate-vlan

[S1-vlan100]access-vlan 10 20

[S1-Vlan100]quit

配置VLAN 100的Vlanif接口，启用ARP Proxy功能。

[S1]interface Vlanif 100

[S1-Vlanif100]ip address 10.0.100.1 24

[S1-Vlanif100]arp-proxy inter-sub-vlan-proxy enable

[S1-Vlanif100]quit

更改R1和R2的IP地址，使其与Vlanif 100接口在同一个网段。并且将网关配置为Vlanif 100的接口地址。

[R1]interface GigabitEthernet 0/0/1

[R1-GigabitEthernet0/0/1]ip address 10.0.100.2 24

[R1-GigabitEthernet0/0/1]quit

[R1]undo ip route-static 0.0.0.0 0 10.0.20.1

[R1]ip route-static 0.0.0.0 0 10.0.100.1

[R2]interface GigabitEthernet 0/0/2

[R2-GigabitEthernet0/0/2]ip address 10.0.100.3 24

[R2-GigabitEthernet0/0/2]quit

[R2]undo ip route-static 0.0.0.0 0 10.0.30.1

[R2]ip route-static 0.0.0.0 0 10.0.100.1

测试R1、R2和S1的Vlanif100接口之间的连通性。

[R1]ping -c 1 10.0.100.1

PING 10.0.100.1: 56 data bytes, press CTRL\_C to break

Reply from 10.0.100.1: bytes=56 Sequence=1 ttl=254 time=3 ms

--- 10.0.100.1 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 10.0.100.3

PING 10.0.100.3: 56 data bytes, press CTRL\_C to break

Reply from 10.0.100.3: bytes=56 Sequence=1 ttl=254 time=2 ms

--- 10.0.100.3 ping statistics ---

1 packet(s) transmitted

1 packet(s) received

0.00% packet loss

round-trip min/avg/max = 2/2/2 ms

[R2]pin -c 1 10.0.100.1

PING 10.0.100.1: 56 data bytes, press CTRL\_C to break

Reply from 10.0.100.1: bytes=56 Sequence=1 ttl=254 time=3 ms

--- 10.0.100.1 ping statistics ---

1 packet(s) transmitted

1 packet(s) received

0.00% packet loss

round-trip min/avg/max = 3/3/3 ms

从**ping**命令的输出结果可知，R1、R2和S1的Vlanif 100接口可以互相通信。相比三层交换方案，VLAN聚合方案能够实现不同VLAN都使用相同的网关通信的功能，有效的减少IP地址的浪费和提高管理效率。但相对的，相同网段的计算机之间互访都依靠同一个Vlanif接口，也使这个接口的压力增大。

## **附加实验: 思考并验证**

多臂路由、单臂路由、VLAN间通信和VLAN聚合这四种方案各自的特点、优缺点和适用场景是怎么样的？

## **最终设备配置**

[S1]**display current-configuration**

!Software Version V200R008C00SPC500

#

sysname S1

#

vlan batch 2 to 3 10 20 100

#

diffserv domain default

#

drop-profile default

#

vlan 100

aggregate-vlan

access-vlan 10 20

#

aaa

authentication-scheme default

authorization-scheme default

accounting-scheme default

domain default

domain default\_admin

local-user admin password irreversible-cipher %^%#tK;J&jw0HG8<9-"zX!kHwzXRNjuXn96[vN47F$\*L~pXcROEP3!>c)NV+:`i;%^%#

local-user admin service-type http

#

interface Vlanif1

#

interface Vlanif2

ip address 10.0.20.1 255.255.255.0

#

interface Vlanif3

ip address 10.0.30.1 255.255.255.0

#

interface Vlanif100

ip address 10.0.100.1 255.255.255.0

arp-proxy inter-sub-vlan-proxy enable

#

interface MEth0/0/1

#

interface GigabitEthernet0/0/1

port link-type access

port default vlan 10

#

interface GigabitEthernet0/0/2

#

interface GigabitEthernet0/0/3

#

interface GigabitEthernet0/0/4

shutdown

port link-type trunk

port trunk allow-pass vlan 2 to 3

#

interface GigabitEthernet0/0/5

#

interface GigabitEthernet0/0/6

#

interface GigabitEthernet0/0/7

#

interface GigabitEthernet0/0/8

#

interface GigabitEthernet0/0/9

port link-type trunk

port trunk allow-pass vlan 2 to 3 10 20

#

interface GigabitEthernet0/0/10

#

interface NULL0

#

user-interface con 0

authentication-mode password

set authentication password cipher $1a$fcjGHMtb0U$^GKZ+`,g@DfG$:T/P,R~iJ&')|!O":$b4)0\*~&c-$

idle-timeout 0 0

user-interface vty 0 4

user-interface vty 16 20

#

return

[S2]**display current-configuration**

!Software Version V200R008C00SPC500

#

sysname S2

#

vlan batch 2 to 3 10 20 100

#

diffserv domain default

#

drop-profile default

#

aaa

authentication-scheme default

authorization-scheme default

accounting-scheme default

domain default

domain default\_admin

local-user admin password irreversible-cipher %^%#gI/bO8qF$HkpAPUgNd'GiYR4TC!>EK#oG("Wl4\_#$G\*OKo-'7\*R[h3+49<Z2%^%#

local-user admin service-type http

#

interface Vlanif1

#

interface MEth0/0/1

#

interface GigabitEthernet0/0/1

#

interface GigabitEthernet0/0/2

port link-type access

port default vlan 20

#

interface GigabitEthernet0/0/3

#

interface GigabitEthernet0/0/4

shutdown

port link-type access

port default vlan 3

#

interface GigabitEthernet0/0/5

#

interface GigabitEthernet0/0/6

#

interface GigabitEthernet0/0/7

#

interface GigabitEthernet0/0/8

#

interface GigabitEthernet0/0/9

port link-type trunk

port trunk allow-pass vlan 2 to 3 10 20

#

interface GigabitEthernet0/0/10

#

user-interface con 0

authentication-mode password

set authentication password cipher $1a$5"l`L7$/5T$,KFQ9dEy~'IggWOa7V(C+9fQOd\*M;U6q,.Sl1y'H$

idle-timeout 0 0

user-interface vty 0 4

user-interface vty 16 20

#

return

[R4]**display current-configuration**

[V200R007C00SPC600]

#

sysname R4

#

board add 0/1 2SA

board add 0/2 2FE

#

drop illegal-mac alarm

#

pki realm default

enrollment self-signed

#

ssl policy default\_policy type server

pki-realm default

#

aaa

authentication-scheme default

authorization-scheme default

accounting-scheme default

domain default

domain default\_admin

local-user admin password irreversible-cipher %^%#`S|f)zA5xQeP^7UA/d/LH:}m3<KxR6fH,g5a%d)'zc,T/&qu:XPCg7))ihy5%^%#

local-user admin privilege level 15

local-user admin service-type terminal http

#

firewall zone Local

priority 64

#

interface Ethernet2/0/0

ip address 10.0.3.1 255.255.255.0

#

interface Ethernet2/0/1

#

interface Serial1/0/0

link-protocol ppp

#

interface Serial1/0/1

link-protocol ppp

#

interface GigabitEthernet0/0/0

#

interface GigabitEthernet0/0/1

ip address 10.0.2.1 255.255.255.0

#

interface GigabitEthernet0/0/1.2

dot1q termination vid 2

ip address 10.0.20.1 255.255.255.0

#

interface GigabitEthernet0/0/1.3

dot1q termination vid 3

ip address 10.0.30.1 255.255.255.0

#

interface GigabitEthernet0/0/2

#

interface GigabitEthernet0/0/3

description VirtualPort

#

interface Cellular0/0/0

#

interface Cellular0/0/1

#

interface NULL0

#

snmp-agent local-engineid 800007DB03D0D04B03D43B

#

http secure-server ssl-policy default\_policy

http server enable

http secure-server enable

#

user-interface con 0

authentication-mode aaa

idle-timeout 0 0

user-interface vty 0

authentication-mode aaa

user privilege level 15

user-interface vty 1 4

#

wlan ac

#

voice

#

diagnose

#

ops

#

autostart

#

return

第七章 STP配置

实验 7-1 STP、RSTP与MSTP的配置

学习目的

* **了解**STP、RSTP与MSTP**的差异**
* **掌握修改网桥优先级影响根网桥选举的方法**
* **掌握修改端口优先级影响根端口与指定端口选举的方法**
* **掌握配置RSTP的方法以及STP与RSTP的相互兼容问题**
* **掌握配置MSTP实现不同VLAN负载均衡的方法**

拓扑图

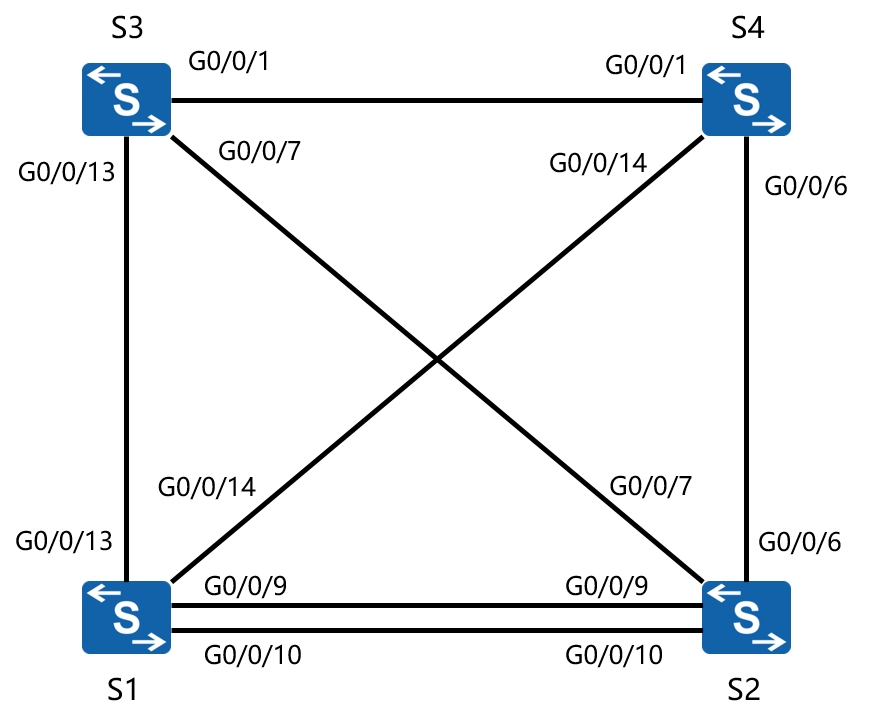


图7-1 STP、RSTP与MSTP实验拓扑图

场景

你是公司的网络管理员。公司的网络采用了备份网络，为避免环路问题，使用STP来进行环路控制。接口在STP的收敛时，所需时间较长，为了加快网络的收敛速度，可以配置RSTP来实现。所有的VLAN共享一棵STP生成树，为了实现VLAN间数据流量的负载均衡，可以配置MSTP来实现。

学习任务

1. STP配置及验证

如果设备默认生成树没有开启，使用以下命令开启。

[S1]stp enable

[S2]stp enable

[S3]stp enable

[S4]stp enable

配置使用传统生成树。

[S1]stp mode stp

[S2]stp mode stp

[S3]stp mode stp

[S4]stp mode stp

查看STP状态信息。

[S1]display stp

-------[CIST Global Info][Mode STP]-------

CIST Bridge :32768.4c1f-cc45-aadc

Bridge Times :Hello 2s MaxAge 20s FwDly 15s MaxHop 20

CIST Root/ERPC :32768.4c1f-cc45-aac1 / 20000

CIST RegRoot/IRPC :32768.4c1f-cc45-aadc / 0

CIST RootPortId :128.9

BPDU-Protection :Disabled

TC or TCN received :36

TC count per hello :2

STP Converge Mode :Normal

Share region-configuration :Enabled

Time since last TC :0 days 0h:0m:1s

……output omit……

[S2]display stp

-------[CIST Global Info][Mode STP]-------

CIST Bridge :32768.4c1f-cc45-aac1

Bridge Times :Hello 2s MaxAge 20s FwDly 15s MaxHop 20

CIST Root/ERPC :32768.4c1f-cc45-aac1 / 0

CIST RegRoot/IRPC :32768.4c1f-cc45-aac1 / 0

CIST RootPortId :0.0

BPDU-Protection :Disabled

TC or TCN received :20

TC count per hello :0

STP Converge Mode :Normal

Share region-configuration :Enabled

Time since last TC :0 days 0h:1m:4s

……output omit……

[S1]display stp brief

MSTID Port Role STP State Protection

0 GigabitEthernet0/0/9 ROOT FORWARDING NONE

0 GigabitEthernet0/0/10 ALTE DISCARDING NONE

0 GigabitEthernet0/0/13 DESI FORWARDING NONE

0 GigabitEthernet0/0/14 DESI FORWARDING NONE

[S2]display stp brief

MSTID Port Role STP State Protection

0 GigabitEthernet0/0/6 DESI FORWARDING NONE

0 GigabitEthernet0/0/7 DESI FORWARDING NONE

0 GigabitEthernet0/0/9 DESI FORWARDING NONE

0 GigabitEthernet0/0/10 DESI FORWARDING NONE

S2为根网桥，所有端口都为指定端口。

实际使用中，由于交换机MAC地址的不可确定性，实际的实验结果可能与如上结果有差异。

1. 根桥选举控制

配置S1为主根网桥，S2为备份根网桥。

[S1]stp root primary

[S2]stp root secondary

查看STP配置信息。

[S1]display stp

-------[CIST Global Info][Mode STP]-------

CIST Bridge :0 .4c1f-cc45-aadc

Bridge Times :Hello 2s MaxAge 20s FwDly 15s MaxHop 20

CIST Root/ERPC :0 .4c1f-cc45-aadc / 0

CIST RegRoot/IRPC :0 .4c1f-cc45-aadc / 0

CIST RootPortId :0.0

BPDU-Protection :Disabled

CIST Root Type :Primary root

TC or TCN received :67

TC count per hello :0

STP Converge Mode :Normal

Share region-configuration :Enabled

Time since last TC :0 days 0h:0m:15s

……output omit……

[S2]display stp

-------[CIST Global Info][Mode STP]-------

CIST Bridge :4096 .4c1f-cc45-aac1

Bridge Times :Hello 2s MaxAge 20s FwDly 15s MaxHop 20

CIST Root/ERPC :0 .4c1f-cc45-aadc / 20000

CIST RegRoot/IRPC :4096 .4c1f-cc45-aac1 / 0

CIST RootPortId :128.9

BPDU-Protection :Disabled

CIST Root Type :Secondary root

TC or TCN received :26

TC count per hello :0

STP Converge Mode :Normal

Share region-configuration :Enabled

Time since last TC :0 days 0h:0m:1s

……output omit……

S1为主根网桥，S2为备份根网桥。

桥优先级数值越小的优先级越高，将S1的桥优先级修改为8192，将S2的桥优先级修改为4096。

[S1]undo stp root

[S1]stp priority 8192

[S2]undo stp root

[S2]stp priority 4096

查看STP信息。

[S1]display stp

-------[CIST Global Info][Mode STP]-------

CIST Bridge :8192 .4c1f-cc45-aadc

Bridge Times :Hello 2s MaxAge 20s FwDly 15s MaxHop 20

CIST Root/ERPC :4096 .4c1f-cc45-aac1 / 20000

CIST RegRoot/IRPC :8192 .4c1f-cc45-aadc / 0

CIST RootPortId :128.9

BPDU-Protection :Disabled

TC or TCN received :79

TC count per hello :1

STP Converge Mode :Normal

Share region-configuration :Enabled

Time since last TC :0 days 0h:0m:0s

……output omit……

[S2]display stp

-------[CIST Global Info][Mode STP]-------

CIST Bridge :4096 .4c1f-cc45-aac1

Bridge Times :Hello 2s MaxAge 20s FwDly 15s MaxHop 20

CIST Root/ERPC :4096 .4c1f-cc45-aac1 / 0

CIST RegRoot/IRPC :4096 .4c1f-cc45-aac1 / 0

CIST RootPortId :0.0

BPDU-Protection :Disabled

TC or TCN received :88

TC count per hello :0

STP Converge Mode :Normal

Share region-configuration :Enabled

Time since last TC :0 days 0h:0m:9s

……output omit……

S1优先级为8192，S2优先级为4096，S2成为根网桥。

1. 根端口选举控制

在S1上查看当前端口角色信息。

[S1]display stp brief

MSTID Port Role STP State Protection

0 GigabitEthernet0/0/9 ROOT FORWARDING NONE

0 GigabitEthernet0/0/10 ALTE DISCARDING NONE

0 GigabitEthernet0/0/13 DESI FORWARDING NONE

0 GigabitEthernet0/0/14 DESI FORWARDING NONE

S1的GigabitEthernet0/0/9为根端口。

端口优先级默认值为128，数值越大优先级越小。

S1与S2通过G0/0/9与G0/0/10接口互联。

将S2的端口G0/0/9端口优先级设置为32，G0/0/10端口优先级设置为16。

[S2]interface GigabitEthernet 0/0/9

[S2-GigabitEthernet0/0/9]stp port priority 32

[S2-GigabitEthernet0/0/9]quit

[S2]interface GigabitEthernet 0/0/10

[S2-GigabitEthernet0/0/10]stp port priority 16

[S2-GigabitEthernet0/0/10]quit

提示：此处是修改S2的端口优先级，而不是修改S1的端口优先级。

在S1上查看当前端口角色信息。

[S1]display stp brief

MSTID Port Role STP State Protection

0 GigabitEthernet0/0/9 ALTE DISCARDING NONE

0 GigabitEthernet0/0/10 ROOT DISCARDING NONE

0 GigabitEthernet0/0/13 DESI FORWARDING NONE

0 GigabitEthernet0/0/14 DESI FORWARDING NONE

S1的GigabitEthernet0/0/10成为根端口。

1. 指定端口选举控制

查看S3和S4直连接口状态。

[S3]display stp interface GigabitEthernet 0/0/1

----[CIST][Port1(GigabitEthernet0/0/1)][DISCARDING]----

Port Protocol :Enabled

Port Role :Alternate Port

Port Priority :128

Port Cost(Dot1T ) :Config=auto / Active=199999

Designated Bridge/Port :32768.5489-98ec-f00a / 128.1

Port Edged :Config=default / Active=disabled

Point-to-point :Config=auto / Active=true

Transit Limit :147 packets/hello-time

Protection Type :None

Port STP Mode :STP

Port Protocol Type :Config=auto / Active=dot1s

PortTimes :Hello 2s MaxAge 20s FwDly 15s RemHop 0

TC or TCN send :17

TC or TCN received :52

BPDU Sent :172

TCN: 0, Config: 172, RST: 0, MST: 0

BPDU Received :206

TCN: 0, Config: 206, RST: 0, MST: 0

[S4]display stp interface GigabitEthernet 0/0/6

----[CIST][Port24(GigabitEthernet0/0/6)][DISCARDING]----

Port Protocol :Enabled

Port Role :Designated Port

Port Priority :128

Port Cost(Dot1T ) :Config=auto / Active=199999

Designated Bridge/Port :32768.5489-98ec-f00a / 128.1

Port Edged :Config=default / Active=disabled

Point-to-point :Config=auto / Active=true

Transit Limit :147 packets/hello-time

Protection Type :None

Port STP Mode :STP

Port Protocol Type :Config=auto / Active=dot1s

PortTimes :Hello 2s MaxAge 20s FwDly 15s RemHop 20

TC or TCN send :37

TC or TCN received :17

BPDU Sent :181

TCN: 0, Config: 181, RST: 0, MST: 0

BPDU Received :172

TCN: 0, Config: 172, RST: 0, MST: 0

S3的GigabitEthernet 0/0/1为替代端口。S4的GigabitEthernet 0/0/1是指定端口。修改S4端口GE0/0/6路径开销为2000000。

[S4]interface GigabitEthernet 0/0/6

[S4-GigabitEthernet0/0/6]stp cost 2000000

[S4-GigabitEthernet0/0/6]quit

查看当前端口角色信息。

[S3]display stp interface GigabitEthernet 0/0/1

----[CIST][Port1(GigabitEthernet0/0/1)][FORWARDING]----

Port Protocol :Enabled

Port Role :Designated Port

Port Priority :128

Port Cost(Dot1T ) :Config=auto / Active=199999

Designated Bridge/Port :32768.5489-98ec-f022 / 128.1

Port Edged :Config=default / Active=disabled

Point-to-point :Config=auto / Active=true

Transit Limit :147 packets/hello-time

Protection Type :None

Port STP Mode :STP

Port Protocol Type :Config=auto / Active=dot1s

PortTimes :Hello 2s MaxAge 20s FwDly 15s RemHop 20

TC or TCN send :52

TC or TCN received :52

BPDU Sent :284

TCN: 0, Config: 284, RST: 0, MST: 0

BPDU Received :380

TCN: 0, Config: 380, RST: 0, MST: 0

[S4]display stp interface GigabitEthernet 0/0/6

----[CIST][Port24(GigabitEthernet0/0/6)][DISCARDING]----

Port Protocol :Enabled

Port Role :Alternate Port

Port Priority :128

Port Cost(Dot1T ) :Config=2000000 / Active=2000000

Designated Bridge/Port :4096.4c1f-cc45-aac1 / 128.24

Port Edged :Config=default / Active=disabled

Point-to-point :Config=auto / Active=true

Transit Limit :147 packets/hello-time

Protection Type :None

Port STP Mode :STP

Port Protocol Type :Config=auto / Active=dot1s

PortTimes :Hello 2s MaxAge 20s FwDly 15s RemHop 0

TC or TCN send :7

TC or TCN received :162

BPDU Sent :8

TCN: 7, Config: 1, RST: 0, MST: 0

BPDU Received :1891

TCN: 0, Config: 1891, RST: 0, MST: 0

S3的GigabitEthernet 0/0/1是指定端口。S4的GigabitEthernet 0/0/1为替代端口。

1. RSTP配置及验证

配置S1和S2的VLANIF 1接口地址。测试S1到S2的连通性。

[S1]interface Vlanif 1

[S1-Vlanif1]ip address 10.0.1.1 24

[S1-Vlanif1]quit

[S2]interface Vlanif 1

[S2-Vlanif1]ip address 10.0.1.2 24

[S2-Vlanif1]quit

[S1]ping 10.0.1.2

PING 10.0.1.2: 56 data bytes, press CTRL\_C to break

Reply from 10.0.1.2: bytes=56 Sequence=1 ttl=255 time=9 ms

Reply from 10.0.1.2: bytes=56 Sequence=2 ttl=254 time=1 ms

Reply from 10.0.1.2: bytes=56 Sequence=3 ttl=254 time=1 ms

Reply from 10.0.1.2: bytes=56 Sequence=4 ttl=254 time=1 ms

Reply from 10.0.1.2: bytes=56 Sequence=5 ttl=254 time=1 ms

--- 10.0.1.2 ping statistics ---

5 packet(s) transmitted

5 packet(s) received

0.00% packet loss

round-trip min/avg/max = 1/2/9 ms

查看S1端口角色信息。

[S1]display stp brief

MSTID Port Role STP State Protection

0 GigabitEthernet0/0/9 ALTE DISCARDING NONE

0 GigabitEthernet0/0/10 ROOT FORWARDING NONE

0 GigabitEthernet0/0/13 DESI FORWARDING NONE

0 GigabitEthernet0/0/14 DESI FORWARDING NONE

S1的GigabitEthernet0/0/10为根端口，用ping测试S1到S2的连通性20次。

提示：S1执行ping操作之后立刻关闭S2的GigabitEthernet 0/0/10接口。

[S1]ping -c 20 10.0.1.2

PING 10.0.1.2: 56 data bytes, press CTRL\_C to break

Reply from 10.0.1.2: bytes=56 Sequence=1 ttl=254 time=1 ms

Reply from 10.0.1.2: bytes=56 Sequence=2 ttl=254 time=1 ms

Dec 21 2011 16:20:44-05:13 S1 %%01IFNET/4/IF\_STATE(l)[5]:Interface GigabitEthernet0/0/10 has turned into DOWN state.

Request time out

Request time out

Request time out

Request time out

Request time out

Request time out

Request time out

Request time out

Request time out

Request time out

Request time out

Request time out

Request time out

Request time out

Request time out

Reply from 10.0.1.2: bytes=56 Sequence=18 ttl=255 time=15 ms

Reply from 10.0.1.2: bytes=56 Sequence=19 ttl=254 time=1 ms

Reply from 10.0.1.2: bytes=56 Sequence=20 ttl=254 time=1 ms

--- 10.0.1.2 ping statistics ---

20 packet(s) transmitted

5 packet(s) received

75.00% packet loss

round-trip min/avg/max = 1/3/15 ms

[S2]interface GigabitEthernet 0/0/10

[S2-GigabitEthernet0/0/10]shutdown

[S2-GigabitEthernet0/0/10]quit

查看S1端口角色信息。

[S1]display stp brief

MSTID Port Role STP State Protection

0 GigabitEthernet0/0/9 ROOT FORWARDING NONE

0 GigabitEthernet0/0/13 DESI FORWARDING NONE

0 GigabitEthernet0/0/14 DESI FORWARDING NONE

S1的GigabitEthernet0/0/9接口成为根端口，端口进入FORWARDING状态，15个包超时，网络收敛时间为30秒。

恢复S2的GigabitEthernet 0/0/10接口。

[S2]interface GigabitEthernet 0/0/10

[S2-GigabitEthernet0/0/10]undo shutdown

[S2-GigabitEthernet0/0/10]quit

配置快速生成树。

[S1]stp mode rstp

[S2]stp mode rstp

[S3]stp mode rstp

[S4]stp mode rstp

查看S1端口角色信息。

[S1]display stp brief

MSTID Port Role STP State Protection

0 GigabitEthernet0/0/9 ALTE DISCARDING NONE

0 GigabitEthernet0/0/10 ROOT FORWARDING NONE

0 GigabitEthernet0/0/13 DESI FORWARDING NONE

0 GigabitEthernet0/0/14 DESI FORWARDING NONE

S1的GigabitEthernet0/0/10为根端口，用**ping**测试S1到S2的连通性20次。

提示：S1上执行ping之后立刻关闭S2的GigabitEthernet 0/0/10。

[S1]ping -c 20 10.0.1.2

PING 10.0.1.2: 56 data bytes, press CTRL\_C to break

Reply from 10.0.1.2: bytes=56 Sequence=1 ttl=254 time=1 ms

Reply from 10.0.1.2: bytes=56 Sequence=2 ttl=254 time=1 ms

Reply from 10.0.1.2: bytes=56 Sequence=3 ttl=254 time=1 ms

Reply from 10.0.1.2: bytes=56 Sequence=4 ttl=254 time=1 ms

Reply from 10.0.1.2: bytes=56 Sequence=5 ttl=254 time=1 ms

Dec 21 2011 16:37:10-05:13 S1 %%01IFNET/4/IF\_STATE(l)[7]:Interface GigabitEthernet0/0/10 has turned into DOWN state.

Request time out

Reply from 10.0.1.2: bytes=56 Sequence=7 ttl=255 time=10 ms

Reply from 10.0.1.2: bytes=56 Sequence=8 ttl=254 time=1 ms

Reply from 10.0.1.2: bytes=56 Sequence=9 ttl=254 time=1 ms

Reply from 10.0.1.2: bytes=56 Sequence=10 ttl=254 time=1 ms

Reply from 10.0.1.2: bytes=56 Sequence=11 ttl=254 time=1 ms

Reply from 10.0.1.2: bytes=56 Sequence=12 ttl=254 time=1 ms

Reply from 10.0.1.2: bytes=56 Sequence=13 ttl=254 time=1 ms

Reply from 10.0.1.2: bytes=56 Sequence=14 ttl=254 time=1 ms

Reply from 10.0.1.2: bytes=56 Sequence=15 ttl=254 time=1 ms

Reply from 10.0.1.2: bytes=56 Sequence=16 ttl=254 time=1 ms

Reply from 10.0.1.2: bytes=56 Sequence=17 ttl=254 time=1 ms

Reply from 10.0.1.2: bytes=56 Sequence=18 ttl=254 time=1 ms

Reply from 10.0.1.2: bytes=56 Sequence=19 ttl=254 time=1 ms

Reply from 10.0.1.2: bytes=56 Sequence=20 ttl=254 time=1 ms

--- 10.0.1.2 ping statistics ---

20 packet(s) transmitted

19 packet(s) received

5.00% packet loss

round-trip min/avg/max = 1/1/10 ms

[S2]interface GigabitEthernet 0/0/10

[S2-GigabitEthernet0/0/10]shutdown

[S2-GigabitEthernet0/0/10]quit

查看S1端口角色信息。

[S1]display stp brief

MSTID Port Role STP State Protection

0 GigabitEthernet0/0/9 ROOT FORWARDING NONE

0 GigabitEthernet0/0/13 DESI FORWARDING NONE

0 GigabitEthernet0/0/14 DESI FORWARDING NONE

S1的GigabitEthernet0/0/9接口成为根端口，进入Forwarding状态。1个包超时，网络收敛时间为2秒。

开启S2的GigabitEthernet 0/0/10接口。

[S2]interface GigabitEthernet 0/0/10

[S2-GigabitEthernet0/0/10]undo shutdown

[S2-GigabitEthernet0/0/10]quit

1. RSTP与STP的兼容

配置S1为STP生成树，其他配置保持不变。

[S1]stp mode stp

查看S1端口角色信息。

[S1]display stp brief

MSTID Port Role STP State Protection

0 GigabitEthernet0/0/9 ALTE DISCARDING NONE

0 GigabitEthernet0/0/10 ROOT FORWARDING NONE

0 GigabitEthernet0/0/13 DESI FORWARDING NONE

0 GigabitEthernet0/0/14 DESI FORWARDING NONE

S1的GigabitEthernet0/0/10为根端口，用ping测试S1到S2的连通性20次。

提示：S1上执行ping之后立刻关闭S2的GigabitEthernet 0/0/10。

[S1]ping -c 20 10.0.1.2

PING 10.0.1.2: 56 data bytes, press CTRL\_C to break

Reply from 10.0.1.2: bytes=56 Sequence=1 ttl=254 time=1 ms

Reply from 10.0.1.2: bytes=56 Sequence=2 ttl=254 time=1 ms

Dec 21 2011 16:20:44-05:13 S1 %%01IFNET/4/IF\_STATE(l)[5]:Interface GigabitEthernet0/0/10 has turned into DOWN state.

Request time out

Request time out

Request time out

Request time out

Request time out

Request time out

Request time out

Request time out

Request time out

Request time out

Request time out

Request time out

Request time out

Request time out

Request time out

Reply from 10.0.1.2: bytes=56 Sequence=18 ttl=255 time=15 ms

Reply from 10.0.1.2: bytes=56 Sequence=19 ttl=254 time=1 ms

Reply from 10.0.1.2: bytes=56 Sequence=20 ttl=254 time=1 ms

--- 10.0.1.2 ping statistics ---

20 packet(s) transmitted

5 packet(s) received

75.00% packet loss

round-trip min/avg/max = 1/3/15 ms

[S2]interface GigabitEthernet 0/0/10

[S2-GigabitEthernet0/0/10]shutdown

查看S1端口角色信息。

[S1]display stp brief

MSTID Port Role STP State Protection

0 GigabitEthernet0/0/9 ROOT FORWARDING NONE

0 GigabitEthernet0/0/13 DESI FORWARDING NONE

0 GigabitEthernet0/0/14 DESI FORWARDING NONE

S1的GigabitEthernet0/0/9接口成为根端口，进入Forwarding状态。15个包超时，网络收敛时间为30秒。

RSTP兼容STP，但收敛方式以STP模式运行。

恢复S2的GigabitEthernet 0/0/10接口。

[S2]interface GigabitEthernet 0/0/10

[S2-GigabitEthernet0/0/10]undo shutdown

[S2-GigabitEthernet0/0/10]quit

1. MSTP的配置与验证

创建VLAN 2到20，并将相应的接口加入到VLAN中。

[S1]vlan batch 2 to 20

Info: This operation may take a few seconds. Please wait for a moment...done.

[S1]interface GigabitEthernet 0/0/9

[S1-GigabitEthernet0/0/9]port link-type trunk

[S1-GigabitEthernet0/0/9]port trunk allow-pass vlan 1 TO 20

[S1-GigabitEthernet0/0/9]quit

[S1]interface GigabitEthernet 0/0/10

[S1-GigabitEthernet0/0/10]port link-type trunk

[S1-GigabitEthernet0/0/10]port trunk allow-pass vlan 1 TO 20

[S1-GigabitEthernet0/0/10]quit

[S1]interface GigabitEthernet 0/0/13

[S1-GigabitEthernet0/0/13]port link-type trunk

[S1-GigabitEthernet0/0/13]port trunk allow-pass vlan 1 TO 20

[S1-GigabitEthernet0/0/13]quit

[S1]interface GigabitEthernet 0/0/14

[S1-GigabitEthernet0/0/14]port link-type trunk

[S1-GigabitEthernet0/0/14]port trunk allow-pass vlan 1 TO 20

[S1-GigabitEthernet0/0/14]quit

[S2]vlan batch 1 to 20

Info: This operation may take a few seconds. Please wait for a moment...done.

[S2]interface GigabitEthernet 0/0/9

[S2-GigabitEthernet0/0/9]port link-type trunk

[S2-GigabitEthernet0/0/9]port trunk allow-pass vlan 1 TO 20

[S2-GigabitEthernet0/0/9]quit

[S2]interface GigabitEthernet 0/0/10

[S2-GigabitEthernet0/0/10]port link-type trunk

[S2-GigabitEthernet0/0/10]port trunk allow-pass vlan 1 TO 20

[S2-GigabitEthernet0/0/10]quit

[S2]interface GigabitEthernet 0/0/7

[S2-GigabitEthernet0/0/7]port link-type trunk

[S2-GigabitEthernet0/0/7]port trunk allow-pass vlan 1 TO 20

[S2-GigabitEthernet0/0/7]quit

[S2]interface GigabitEthernet 0/0/6

[S2-GigabitEthernet0/0/6]port link-type trunk

[S2-GigabitEthernet0/0/6]port trunk allow-pass vlan 1 TO 20

[S2-GigabitEthernet0/0/6]quit

[S3]vlan batch 1 to 20

Info: This operation may take a few seconds. Please wait for a moment...done.

[S3]interface GigabitEthernet0/0/1

[S3-GigabitEthernet0/0/1]port link-type trunk

[S3-GigabitEthernet0/0/1]port trunk allow-pass vlan 1 TO 20

[S3-GigabitEthernet0/0/1]quit

[S3]interface GigabitEthernet0/0/13

[S3-GigabitEthernet0/0/13]port link-type trunk

[S3-GigabitEthernet0/0/13]port trunk allow-pass vlan 1 TO 20

[S3-GigabitEthernet0/0/13]quit

[S3]interface GigabitEthernet0/0/7

[S3-GigabitEthernet0/0/7]port link-type trunk

[S3-GigabitEthernet0/0/7]port trunk allow-pass vlan 1 TO 20

[S3-GigabitEthernet0/0/7]quit

[S4]vlan batch 1 to 20

Info: This operation may take a few seconds. Please wait for a moment...done.

[S4]interface GigabitEthernet0/0/1

[S4-GigabitEthernet0/0/1]port link-type trunk

[S4-GigabitEthernet0/0/1]port trunk allow-pass vlan 1 TO 20

[S4-GigabitEthernet0/0/1]quit

[S4]interface GigabitEthernet0/0/6

[S4-GigabitEthernet0/0/6]port link-type trunk

[S4-GigabitEthernet0/0/6]port trunk allow-pass vlan 1 TO 20

[S4-GigabitEthernet0/0/6]quit

[S4]interface GigabitEthernet0/0/14

[S4-GigabitEthernet0/0/14]port link-type trunk

[S4-GigabitEthernet0/0/14]port trunk allow-pass vlan 1 TO 20

[S4-GigabitEthernet0/0/14]quit

配置MSTP。

定义VLAN1-10属于INSTANCE 1，VLAN11-20属于INSTANCE 2。

[S1]stp mode mstp

[S1]stp region-configuration

[S1-mst-region]region-name RG1

[S1-mst-region]instance 1 vlan 1 TO 10

[S1-mst-region]instance 2 vlan 11 to 20

[S1-mst-region]active region-configuration

Info: This operation may take a few seconds. Please wait for a moment....done.

[S1-mst-region]quit

[S2]stp mode mstp

[S2]stp region-configuration

[S2-mst-region]region-name RG1

[S2-mst-region]instance 1 vlan 1 TO 10

[S2-mst-region]instance 2 vlan 11 to 20

[S2-mst-region]active region-configuration

Info: This operation may take a few seconds. Please wait for a moment....done.

[S2-mst-region]quit

[S3]STP mode mstp

Info: This operation may take a few seconds. Please wait for a moment.....done.

[S3]stp region-configuration

[S3-mst-region]region-name RG1

[S3-mst-region]instance 1 vlan 1 to 10

[S3-mst-region]instance 2 vlan 11 to 20

[S3-mst-region]quit

[S4]STP mode mstp

Info: This operation may take a few seconds. Please wait for a moment.....done.

[S4]stp region-configuration

[S4-mst-region]region-name RG1

[S4-mst-region]instance 1 vlan 1 to 10

[S4-mst-region]instance 2 vlan 11 to 20

[S4-mst-region]quit

查看MSTP实例和VLAN的映射关系。

[S1]display stp region-configuration

Oper configuration

Format selector :0

Region name :RG1

Revision level :0

Instance VLANs Mapped

0 21 to 4094

1 1 to 10

2 11 to 20

配置S1在实例1中的优先级为4096, 在实例2中的优先级为8192。

配置S2在实例2中的优先级为4096，在实例1中的优先级为8192。

[S1]stp instance 1 priority 4096

[S1]stp instance 2 priority 8192

[S2]stp instance 2 priority 4096

[S2]stp instance 1 priority 8192

查看实例1和实例2的状态信息。

[S1]display stp instance 1

-------[MSTI 1 Global Info]-------

MSTI Bridge ID :4096.4c1f-cc45-aadc

MSTI RegRoot/IRPC :4096.4c1f-cc45-aadc / 0

MSTI RootPortId :0.0

Master Bridge :4096.4c1f-cc45-aac1

Cost to Master :20000

TC received :20

TC count per hello :0

[S2]display stp instance 2

-------[MSTI 2 Global Info]-------

MSTI Bridge ID :4096.4c1f-cc45-aac1

MSTI RegRoot/IRPC :4096.4c1f-cc45-aac1 / 0

MSTI RootPortId :0.0

Master Bridge :4096.4c1f-cc45-aac1

Cost to Master :0

TC received :16

TC count per hello :0

S1为实例1的根桥，S2为实例2的根桥。

查看MSTP实例1端口角色。

[S1]display stp instance 1 brief

MSTID Port Role STP State Protection

1 GigabitEthernet0/0/9 DESI FORWARDING NONE

1 GigabitEthernet0/0/10 DESI FORWARDING NONE

1 GigabitEthernet0/0/13 DESI FORWARDING NONE

1 GigabitEthernet0/0/14 DESI FORWARDING NONE

[S2]display stp instance 1 brief

MSTID Port Role STP State Protection

1 GigabitEthernet0/0/6 DESI FORWARDING NONE

1 GigabitEthernet0/0/7 DESI FORWARDING NONE

1 GigabitEthernet0/0/9 ROOT FORWARDING NONE

1 GigabitEthernet0/0/10 ALTE DISCARDING NONE

[S3]display stp instance 1 brief

MSTID Port Role STP State Protection

1 GigabitEthernet0/0/1 ALTE DISCARDING NONE

1 GigabitEthernet0/0/13 ROOT FORWARDING NONE

1 GigabitEthernet0/0/7 ALTE DISCARDING NONE

[S4]display stp instance 1 brief

MSTID Port Role STP State Protection

1 GigabitEthernet0/0/1 DESI FORWARDING NONE

1 GigabitEthernet0/0/6 ALTE DISCARDING NONE

1 GigabitEthernet0/0/14 ROOT FORWARDING NONE

实例1中S1为根网桥，S3的VLAN 1到VLAN10的用户经过Ethernet0/0/13接口和S1、S2、S4的VLAN 1到VLAN10的用户通讯。

查看MSTP实例2端口角色。

[S1]display stp instance 2 brief

MSTID Port Role STP State Protection

2 GigabitEthernet0/0/9 ROOT FORWARDING NONE

2 GigabitEthernet0/0/10 ALTE DISCARDING NONE

2 GigabitEthernet0/0/13 DESI FORWARDING NONE

[S2]display stp instance 2 brief

MSTID Port Role STP State Protection

2 GigabitEthernet0/0/6 DESI FORWARDING NONE

2 GigabitEthernet0/0/7 DESI FORWARDING NONE

2 GigabitEthernet0/0/9 DESI FORWARDING NONE

2 GigabitEthernet0/0/10 DESI FORWARDING NONE

[S3]display stp instance 2 brief

MSTID Port Role STP State Protection

2 GigabitEthernet0/0/1 ALTE DISCARDING NONE

2 GigabitEthernet0/0/7 ROOT FORWARDING NONE

2 GigabitEthernet0/0/13 ALTE DISCARDING NONE

[S4]display stp instance 2 brief

MSTID Port Role STP State Protection

2 GigabitEthernet0/0/1 DESI FORWARDING NONE

2 GigabitEthernet0/0/6 ROOT FORWARDING NONE

2 GigabitEthernet0/0/14 DESI FORWARDING NONE

实例2中S2为根网桥，S3的VLAN 11到VLAN 20经过Ethernet0/0/23和S1、S2、S4的VLAN 11到VLAN 20通讯。

附加实验: 思考并验证

MSTP如何在多个区域实现不同VLAN数据传输的均衡？

RSTP快速转发的原因是什么？

最终设备配置

[S1]display current-configuration

#

!Software Version V200R008C00SPC500

sysname S1

#

vlan batch 2 to 20

#

stp instance 0 priority 8192

stp instance 1 priority 4096

stp instance 2 priority 8192

#

stp region-configuration

region-name RG1

instance 1 vlan 1 to 10

instance 2 vlan 11 to 20

active region-configuration

#

interface Vlanif1

ip address 10.0.1.1 255.255.255.0

#

interface GigabitEthernet0/0/9

port link-type trunk

port trunk allow-pass vlan 2 to 20

#

interface GigabitEthernet0/0/10

port link-type trunk

port trunk allow-pass vlan 2 to 20

#

interface GigabitEthernet0/0/13

port link-type trunk

port trunk allow-pass vlan 2 to 20

#

Return

[S2]display current-configuration

#

!Software Version V200R008C00SPC500

sysname S2

#

vlan batch 2 to 20

#

stp instance 0 priority 4096

stp instance 1 priority 8192

stp instance 2 priority 4096

#

stp region-configuration

region-name RG1

instance 1 vlan 1 to 10

instance 2 vlan 11 to 20

active region-configuration

#

interface Vlanif1

ip address 10.0.1.2 255.255.255.0

#

interface GigabitEthernet0/0/6

port link-type trunk

port trunk allow-pass vlan 2 to 20

#

interface GigabitEthernet0/0/7

port link-type trunk

port trunk allow-pass vlan 2 to 20

#

interface GigabitEthernet0/0/9

port link-type trunk

port trunk allow-pass vlan 2 to 20

stp instance 0 port priority 32

#

interface GigabitEthernet0/0/10

port link-type trunk

port trunk allow-pass vlan 2 to 20

stp instance 0 port priority 16

#

Return

[S3]display current-configuration

#

!Software Version V100R006C05

sysname S3

#

vlan batch 2 to 20

#

stp region-configuration

region-name RG1

instance 1 vlan 1 to 10

instance 2 vlan 11 to 20

active region-configuration

#

interface GigabitEthernet0/0/1

port link-type trunk

port trunk allow-pass vlan 2 to 20

#

interface GigabitEthernet0/0/7

port link-type trunk

port trunk allow-pass vlan 2 to 20

#

interface GigabitEthernet0/0/13

port link-type trunk

port trunk allow-pass vlan 2 to 20

#

Return

[S4]display current-configuration

#

!Software Version V100R006C05

sysname S4

#

vlan batch 2 to 20

#

stp region-configuration

region-name RG1

instance 1 vlan 1 to 10

instance 2 vlan 11 to 20

active region-configuration

#

interface GigabitEthernet0/0/1

port link-type trunk

port trunk allow-pass vlan 2 to 20

#

interface GigabitEthernet0/0/6

port link-type trunk

port trunk allow-pass vlan 2 to 20

stp instance 0 cost 2000000

#

interface GigabitEthernet0/0/7

#

interface GigabitEthernet0/0/14

port link-type trunk

port trunk allow-pass vlan 2 to 20

#

Return

实验 7-2 MSTP多区域与STP的兼容（选做）

学习目的

* 掌握MSTP多实例以及多区域的配置方法
* 掌握实现MSTP与相STP兼容的配置方法
* 掌握MSTP边缘端口保护、指定端口保护、环路保护、TC-BPDU保护的配置方法

## **拓扑图**

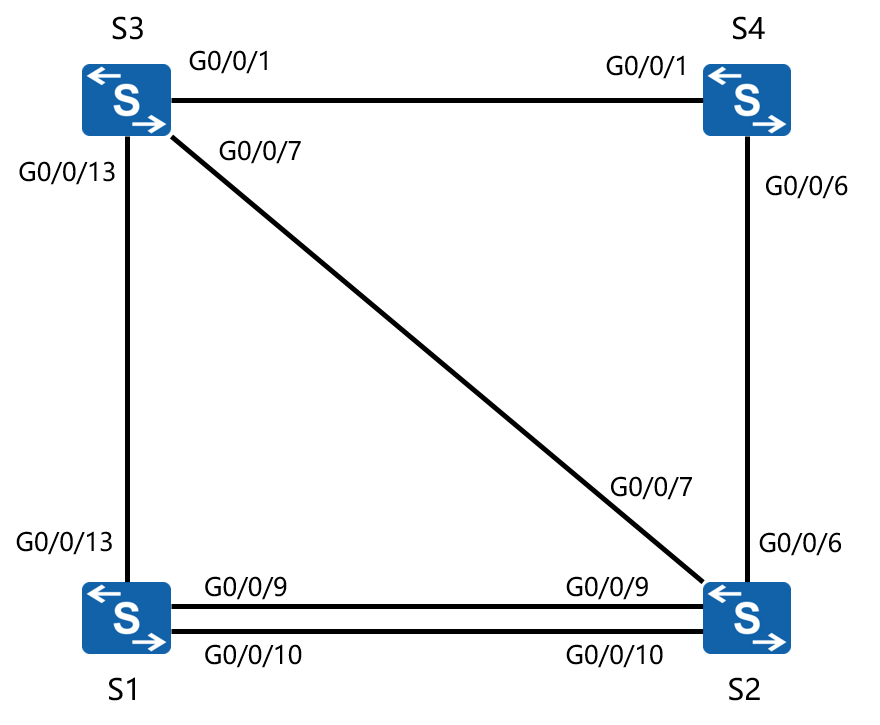


图7-2 MSTP多区域与STP的兼容

## **场景**

你是公司的网络管理员。在公司的二层网络架构中，为了克服单个生成树的会造成部分VLAN路径不通及次优路径等种种弊端，并且实现流量的分担。在网络中部署MSTP协议，并能实现与传统单生成树之间的相互兼容。

## **学习任务**

1. 基本配置

在本实验之前，需要关闭一些不使用的接口。

<S1>system-view

Enter system view, return user view with Ctrl+Z.

[S1]interface GigabitEthernet 0/0/9

[S1-GigabitEthernet0/0/9]shutdown

[S1-GigabitEthernet0/0/9]quit

<S3>system-view

Enter system view, return user view with Ctrl+Z.

[S3]interface GigabitEthernet 0/0/7

[S3-GigabitEthernet0/0/7]shutdown

[S3-GigabitEthernet0/0/7]quit

<S4>system-view

Enter system view, return user view with Ctrl+Z.

[S4]interface GigabitEthernet 0/0/14

[S4-GigabitEthernet0/0/14]shutdown

[S4-GigabitEthernet0/0/14]quit

所有交换机上都创建VLAN 3,4,5,6,7,8，

[S1]vlan batch 3 to 8

[S2]vlan batch 3 to 8

[S3]vlan batch 3 to 8

[S4]vlan batch 3 to 8

查看创建的VLAN，

[S1]**display vlan**

\* : management-vlan

---------------------

The total number of vlans is : 7

VLAN ID Type Status MAC Learning Broadcast/Multicast/Unicast Property

----------------------------------------------------------------------------

1 common enable enable forward forward forward default

3 common enable enable forward forward forward default

4 common enable enable forward forward forward default

5 common enable enable forward forward forward default

6 common enable enable forward forward forward default

7 common enable enable forward forward forward default

8 common enable enable forward forward forward default

[S2]**display vlan**

\* : management-vlan

---------------------

The total number of vlans is : 7

VLAN ID Type Status MAC Learning Broadcast/Multicast/Unicast Property

----------------------------------------------------------------------------

1 common enable enable forward forward forward default

3 common enable enable forward forward forward default

4 common enable enable forward forward forward default

5 common enable enable forward forward forward default

6 common enable enable forward forward forward default

7 common enable enable forward forward forward default

8 common enable enable forward forward forward default

[S3]**display vlan**

\* : management-vlan

---------------------

The total number of vlans is : 7

VLAN ID Type Status MAC Learning Broadcast/Multicast/Unicast Property

----------------------------------------------------------------------------

1 common enable enable forward forward forward default

3 common enable enable forward forward forward default

4 common enable enable forward forward forward default

5 common enable enable forward forward forward default

6 common enable enable forward forward forward default

7 common enable enable forward forward forward default

8 common enable enable forward forward forward default

[S4]**display vlan**

\* : management-vlan

---------------------

The total number of vlans is : 7

VLAN ID Type Status MAC Learning Broadcast/Multicast/Unicast Property

----------------------------------------------------------------------------

1 common enable enable forward forward forward default

3 common enable enable forward forward forward default

4 common enable enable forward forward forward default

5 common enable enable forward forward forward default

6 common enable enable forward forward forward default

7 common enable enable forward forward forward default

8 common enable enable forward forward forward default

设置所有交换机之间链路类型全部为Trunk链路，接收BPDU，并且允许所有VLAN通过。注意S2与S3之间的直连链路此时不做任何配置。

[S1]interface GigabitEthernet 0/0/13

[S1-GigabitEthernet0/0/13]port link-type trunk

[S1-GigabitEthernet0/0/13]port trunk allow-pass vlan all

[S1-GigabitEthernet0/0/13]bpdu enable

[S1-GigabitEthernet0/0/13]quit

[S1]interface GigabitEthernet 0/0/10

[S1-GigabitEthernet0/0/10]port link-type trunk

[S1-GigabitEthernet0/0/10]port trunk allow-pass vlan all

[S1-GigabitEthernet0/0/10]bpdu enable

[S1-GigabitEthernet0/0/10]quit

[S2]interface GigabitEthernet 0/0/6

[S2-GigabitEthernet0/0/6]port link-type trunk

[S2-GigabitEthernet0/0/6]port trunk allow-pass vlan all

[S2-GigabitEthernet0/0/6]bpdu enable

[S2-GigabitEthernet0/0/6]quit

[S2]interface GigabitEthernet 0/0/10

[S2-GigabitEthernet0/0/10]port link-type trunk

[S2-GigabitEthernet0/0/10]port trunk allow-pass vlan all

[S2-GigabitEthernet0/0/10]bpdu enable

[S2-GigabitEthernet0/0/10]quit

[S3]interface GigabitEthernet0/0/1

[S3-GigabitEthernet0/0/1]port link-type trunk

[S3-GigabitEthernet0/0/1]port trunk allow-pass vlan all

[S3-GigabitEthernet0/0/1]bpdu enable

[S3-GigabitEthernet0/0/1]quit

[S3]interface GigabitEthernet0/0/13

[S3-GigabitEthernet0/0/13]port link-type trunk

[S3-GigabitEthernet0/0/13]port trunk allow-pass vlan all

[S3-GigabitEthernet0/0/13]bpdu enable

[S3-GigabitEthernet0/0/13]quit

[S4]interface GigabitEthernet0/0/1

[S4-GigabitEthernet0/0/1]port link-type trunk

[S4-GigabitEthernet0/0/1]port trunk allow-pass vlan all

[S4-GigabitEthernet0/0/1]bpdu enable

[S4-GigabitEthernet0/0/1]quit

[S4]interface GigabitEthernet0/0/6

[S4-GigabitEthernet0/0/6]port link-type trunk

[S4-GigabitEthernet0/0/6]port trunk allow-pass vlan all

[S4-GigabitEthernet0/0/6]bpdu enable

[S4-GigabitEthernet0/0/6]quit

1. 配置MSTP多实例

在系统视图下，启用MSTP，

[S1]stp enable

[S1]stp mode mstp

[S2]stp enable

[S2]stp mode mstp

[S3]stp enable

[S3]stp mode mstp

[S4]stp enable

[S4]stp mode mstp

配置所有交换机都属于同一个区域RG1，修订级别为1。建实例1和VLAN 3,4,5建立映射关系，创建实例2和VLAN 6,7,8建立映射关系，并激活域配置。

[S1]stp region-configuration

[S1-mst-region]region-name RG1

[S1-mst-region]revision-level 1

[S1-mst-region]instance 1 vlan 3 4 5

[S1-mst-region]instance 2 vlan 6 7 8

[S1-mst-region]active region-configuration

[S1-mst-region]quit

[S2]stp region-configuration

[S2-mst-region]region-name RG1

[S2-mst-region]revision-level 1

[S2-mst-region]instance 1 vlan 3 4 5

[S2-mst-region]instance 2 vlan 6 7 8

[S2-mst-region]active region-configuration

[S2-mst-region]quit

[S3]stp region-configuration

[S3-mst-region]region-name RG1

[S3-mst-region]revision-level 1

[S3-mst-region]instance 1 vlan 3 4 5

[S3-mst-region]instance 2 vlan 6 7 8

[S3-mst-region]active region-configuration

[S3-mst-region]quit

[S4]stp region-configuration

[S4-mst-region]region-name RG1

[S4-mst-region]revision-level 1

[S4-mst-region]instance 1 vlan 3 4 5

[S4-mst-region]instance 2 vlan 6 7 8

[S4-mst-region]active region-configuration

[S4-mst-region]quit

完成后查看MSTP信息，

[S1]**display stp brief**

MSTID Port Role STP State Protection

0 GigabitEthernet0/0/10 DESI FORWARDING NONE

0 GigabitEthernet0/0/13 DESI FORWARDING NONE

1 GigabitEthernet0/0/10 DESI FORWARDING NONE

1 GigabitEthernet0/0/13 DESI FORWARDING NONE

2 GigabitEthernet0/0/10 DESI FORWARDING NONE

2 GigabitEthernet0/0/13 DESI FORWARDING NONE

[S2]**display stp brief**

MSTID Port Role STP State Protection

0 GigabitEthernet0/0/6 DESI FORWARDING NONE

0 GigabitEthernet0/0/10 ROOT FORWARDING NONE

1 GigabitEthernet0/0/6 DESI FORWARDING NONE

1 GigabitEthernet0/0/10 ROOT FORWARDING NONE

2 GigabitEthernet0/0/6 DESI FORWARDING NONE

2 GigabitEthernet0/0/10 ROOT FORWARDING NONE

[S3]**display stp brief**

MSTID Port Role STP State Protection

0 GigabitEthernet0/0/1 DESI FORWARDING NONE

0 GigabitEthernet0/0/13 ROOT FORWARDING NONE

1 GigabitEthernet0/0/1 DESI FORWARDING NONE

1 GigabitEthernet0/0/13 ROOT FORWARDING NONE

2 GigabitEthernet0/0/1 DESI FORWARDING NONE

2 GigabitEthernet0/0/13 ROOT FORWARDING NONE

[S4]**display stp brief**

MSTID Port Role STP State Protection

0 GigabitEthernet0/0/1 ROOT FORWARDING NONE

0 GigabitEthernet0/0/6 ALTE DISCARDING NONE

1 GigabitEthernet0/0/1 ROOT FORWARDING NONE

1 GigabitEthernet0/0/6 ALTE DISCARDING NONE

2 GigabitEthernet0/0/1 ROOT FORWARDING NONE

2 GigabitEthernet0/0/6 ALTE DISCARDING NONE

此时S1为根交换机，S4上的E0/0/24端口为所有MSTP进程的备用端口。

在实例2中，设置S2的优先级为0，S1的优先级为4096，S4的优先级为8192，使S2成为实例2中的根交换机。

[S2]stp instance 2 priority 0

[S1]stp instance 2 priority 4096

[S4]stp instance 2 priority 8192

配置完成后，查看MSTP的基本信息。

[S1]**display stp brief**

MSTID Port Role STP State Protection

0 GigabitEthernet0/0/10 DESI FORWARDING NONE

0 GigabitEthernet0/0/13 DESI FORWARDING NONE

1 GigabitEthernet0/0/10 DESI FORWARDING NONE

1 GigabitEthernet0/0/13 DESI FORWARDING NONE

2 GigabitEthernet0/0/10 ROOT FORWARDING NONE

2 GigabitEthernet0/0/13 DESI FORWARDING NONE

[S2]**display stp brief**

MSTID Port Role STP State Protection

0 GigabitEthernet0/0/6 DESI FORWARDING NONE

0 GigabitEthernet0/0/10 ROOT FORWARDING NONE

1 GigabitEthernet0/0/6 DESI FORWARDING NONE

1 GigabitEthernet0/0/10 ROOT FORWARDING NONE

2 GigabitEthernet0/0/6 DESI FORWARDING NONE

2 GigabitEthernet0/0/10 DESI FORWARDING NONE

[S3]**display stp brief**

MSTID Port Role STP State Protection

0 GigabitEthernet0/0/1 DESI FORWARDING NONE

0 GigabitEthernet0/0/13 ROOT FORWARDING NONE

1 GigabitEthernet0/0/1 DESI FORWARDING NONE

1 GigabitEthernet0/0/13 ROOT FORWARDING NONE

2 GigabitEthernet0/0/1 ALTE DISCARDING NONE

2 GigabitEthernet0/0/13 ROOT FORWARDING NONE

[S4]**display stp brief**

MSTID Port Role STP State Protection

0 GigabitEthernet0/0/1 ALTE DISCARDING NONE

0 GigabitEthernet0/0/6 ROOT FORWARDING NONE

1 GigabitEthernet0/0/1 ALTE DISCARDING NONE

1 GigabitEthernet0/0/6 ROOT FORWARDING NONE

2 GigabitEthernet0/0/1 DESI FORWARDING NONE

2 GigabitEthernet0/0/6 ROOT FORWARDING NONE

此时S2成为了实例2中的根交换机，S3的E0/0/1成为实例2中的预备端口。但各交换机在实例1中的状态没有改变，验证了每个MST实例都独立计算生成树，互不影响。

1. 配置MSTP多区域

删除步骤二中所有交换机上的MSTP区域以及优先级的配置。

[S1]undo stp region-configuration

[S1]undo stp instance 2 priority

[S2]undo stp region-configuration

[S2]undo stp instance 2 priority

[S3]undo stp region-configuration

[S4]undo stp region-configuration

[S4]undo stp instance 2 priority

配置S1和S3到一个MSTP域内，域名为RG1，修订版本号为1。

创建实例1，与VLAN 3,4,5，建立映射关系。

创建实例2，与VLAN 6,7,8,建立映射关系。

[S1]stp region-configuration

[S1-mst-region]region-name RG1

[S1-mst-region]revision-level 1

[S1-mst-region]instance 1 vlan 3 4 5

[S1-mst-region]instance 2 vlan 6 7 8

[S1-mst-region]active region-configuration

[S1-mst-region]quit

[S3]stp region-configuration

[S3-mst-region]region-name RG1

[S3-mst-region]revision-level 1

[S3-mst-region]instance 1 vlan 3 4 5

[S3-mst-region]instance 2 vlan 6 7 8

[S3-mst-region]active region-configuration

[S3-mst-region]quit

将S2和S4配置到另一个MSTP域内，域名为RG2，修订版本号为2。

创建实例1，和VLAN 3,4,5建立映射关系。

创建实例2，与VLAN 6,7,8建立映射关系，并全部激活域配置，

[S2]stp region-configuration

[S2-mst-region]region-name RG2

[S2-mst-region]revision-level 2

[S2-mst-region]instance 1 vlan 3 4 5

[S2-mst-region]instance 2 vlan 6 7 8

[S2-mst-region]active region-configuration

[S2-mst-region]quit

[S4]stp region-configuration

[S4-mst-region]region-name RG2

[S4-mst-region]revision-level 2

[S4-mst-region]instance 1 vlan 3 4 5

[S4-mst-region]instance 2 vlan 6 7 8

[S4-mst-region]active region-configuration

[S4-mst-region]quit

配置完成后，查看MSTP基本信息。

[S1]**display stp brief**

MSTID Port Role STP State Protection

0 GigabitEthernet0/0/10 DESI FORWARDING NONE

0 GigabitEthernet0/0/13 DESI FORWARDING NONE

1 GigabitEthernet0/0/10 DESI FORWARDING NONE

1 GigabitEthernet0/0/13 DESI FORWARDING NONE

2 GigabitEthernet0/0/10 DESI FORWARDING NONE

2 GigabitEthernet0/0/13 DESI FORWARDING NONE

[S2]**display stp brief**

MSTID Port Role STP State Protection

0 GigabitEthernet0/0/6 DESI FORWARDING NONE

0 GigabitEthernet0/0/10 ROOT FORWARDING NONE

1 GigabitEthernet0/0/6 DESI FORWARDING NONE

1 GigabitEthernet0/0/10 MAST FORWARDING NONE

2 GigabitEthernet0/0/10 MAST FORWARDING NONE

[S3]**display stp brief**

MSTID Port Role STP State Protection

0 GigabitEthernet0/0/1 DESI FORWARDING NONE

0 GigabitEthernet0/0/13 ROOT FORWARDING NONE

1 GigabitEthernet0/0/1 DESI FORWARDING NONE

1 GigabitEthernet0/0/13 ROOT FORWARDING NONE

2 GigabitEthernet0/0/1 DESI FORWARDING NONE

2 GigabitEthernet0/0/13 ROOT FORWARDING NONE

[S4]**display stp brief**

MSTID Port Role STP State Protection

0 GigabitEthernet0/0/1 ALTE DISCARDING NONE

0 GigabitEthernet0/0/6 ROOT FORWARDING NONE

1 GigabitEthernet0/0/1 ALTE DISCARDING NONE

1 GigabitEthernet0/0/6 ROOT FORWARDING NONE

2 GigabitEthernet0/0/1 ALTE DISCARDING NONE

2 GigabitEthernet0/0/6 ROOT FORWARDING NONE

此时S1为根交换机，S4上的E0/0/1为预备端口。

配置S3在实例0中优先级为0，使其成为CIST的总根，配置S3在实例1中的优先级为0，使其成为实例1的域根，配置S4在实例1中的优先级为0，使其成为实例1的域根。

[S3]stp instance 0 priority 0

[S3]stp instance 1 priority 0

[S4]stp instance 1 priority 0

配置完成后，查看MSTP基本信息。

[S1]**display stp brief**

MSTID Port Role STP State Protection

0 GigabitEthernet0/0/10 DESI FORWARDING NONE

0 GigabitEthernet0/0/13 ROOT FORWARDING NONE

1 GigabitEthernet0/0/10 DESI FORWARDING NONE

1 GigabitEthernet0/0/13 ROOT FORWARDING NONE

2 GigabitEthernet0/0/10 DESI FORWARDING NONE

2 GigabitEthernet0/0/13 DESI FORWARDING NONE

[S2]**display stp brief**

MSTID Port Role STP State Protection

0 GigabitEthernet0/0/6 DESI FORWARDING NONE

0 GigabitEthernet0/0/10 ROOT FORWARDING NONE

1 GigabitEthernet0/0/6 ROOT FORWARDING NONE

1 GigabitEthernet0/0/10 MAST FORWARDING NONE

2 GigabitEthernet0/0/6 DESI FORWARDING NONE

2 GigabitEthernet0/0/10 MAST FORWARDING NONE

[S3]**display stp brief**

MSTID Port Role STP State Protection

0 GigabitEthernet0/0/1 DESI FORWARDING NONE

0 GigabitEthernet0/0/13 DESI FORWARDING NONE

1 GigabitEthernet0/0/1 DESI FORWARDING NONE

1 GigabitEthernet0/0/13 DESI FORWARDING NONE

2 GigabitEthernet0/0/1 DESI FORWARDING NONE

2 GigabitEthernet0/0/13 ROOT FORWARDING NONE

[S4]**display stp brief**

MSTID Port Role STP State Protection

0 GigabitEthernet0/0/1 ALTE DISCARDING NONE

0 GigabitEthernet0/0/6 ROOT FORWARDING NONE

1 GigabitEthernet0/0/1 ALTE DISCARDING NONE

1 GigabitEthernet0/0/6 DESI FORWARDING NONE

2 GigabitEthernet0/0/1 ALTE DISCARDING NONE

2 GigabitEthernet0/0/6 ROOT FORWARDING NONE

删除S2和S4上的MSTP配置，将S2和S4配置到另一个MSTP域内，域名为RG2，修订版本号为2。创建实例1，和VLAN 6,7,8建立映射关系，创建实例2，与VLAN 3,4,5建立映射关系，并全部激活域配置，

[S2]undo stp region-configuration

[S3]undo stp instance 0 priority

[S3]undo stp instance 1 priority

[S4]undo stp region-configuration

[S4]undo stp instance 1 priority

[S2]stp region-configuration

[S2-mst-region]region-name RG2

[S2-mst-region]revision-level 2

[S2-mst-region]instance 1 vlan 6 7 8

[S2-mst-region]instance 2 vlan 3 4 5

[S2-mst-region]active region-configuration

[S2-mst-region]quit

[S4]stp region-configuration

[S4-mst-region]region-name RG2

[S4-mst-region]revision-level 2

[S4-mst-region]instance 1 vlan 6 7 8

[S4-mst-region]instance 2 vlan 3 4 5

[S4-mst-region]active region-configuration

[S4-mst-region]quit

配置完成后，查看MSTP基本信息。

[S1]**display stp brief**

MSTID Port Role STP State Protection

0 GigabitEthernet0/0/10 DESI FORWARDING NONE

0 GigabitEthernet0/0/13 DESI FORWARDING NONE

1 GigabitEthernet0/0/10 DESI FORWARDING NONE

1 GigabitEthernet0/0/13 DESI FORWARDING NONE

2 GigabitEthernet0/0/10 DESI FORWARDING NONE

2 GigabitEthernet0/0/13 DESI FORWARDING NONE

[S2]**display stp brief**

MSTID Port Role STP State Protection

0 GigabitEthernet0/0/6 DESI FORWARDING NONE

0 GigabitEthernet0/0/10 ROOT FORWARDING NONE

1 GigabitEthernet0/0/6 DESI FORWARDING NONE

1 GigabitEthernet0/0/10 MAST FORWARDING NONE

2 GigabitEthernet0/0/6 DESI FORWARDING NONE

2 GigabitEthernet0/0/10 MAST FORWARDING NONE

[S3]**display stp brief**

MSTID Port Role STP State Protection

0 GigabitEthernet0/0/1 DESI FORWARDING NONE

0 GigabitEthernet0/0/13 ROOT FORWARDING NONE

1 GigabitEthernet0/0/1 DESI FORWARDING NONE

1 GigabitEthernet0/0/13 ROOT FORWARDING NONE

2 GigabitEthernet0/0/1 DESI FORWARDING NONE

2 GigabitEthernet0/0/13 ROOT FORWARDING NONE

[S4]**display stp brief**

MSTID Port Role STP State Protection

0 GigabitEthernet0/0/1 ALTE DISCARDING NONE

0 GigabitEthernet0/0/6 ROOT FORWARDING NONE

1 GigabitEthernet0/0/1 ALTE DISCARDING NONE

1 GigabitEthernet0/0/6 ROOT FORWARDING NONE

2 GigabitEthernet0/0/1 ALTE DISCARDING NONE

除了Instance 0之外，每个区域的MST实例都独立计算生成树，不管是否包含相同的VLAN，不管VLAN是否和实例映射一致，区域内的生成树计算相互之间互不影响。

1. 配置MSTP与STP兼容

将S1，S2，S3配置在一个MSTP域中，S4单独配置STP。

删除S2上的MSTP配置，在S2上重新创建MSTP。域名为RG1，创建实例1与VLAN 3,4,5，建立映射关系。创建实例2与VLAN6,7,8建立映射关系，并激活域配置。

[S2]undo stp region-configuration

[S2]stp region-configuration

[S2-mst-region]region-name RG1

[S2-mst-region]revision-level 1

[S2-mst-region]instance 1 vlan 3 4 5

[S2-mst-region]instance 2 vlan 6 7 8

[S2-mst-region]active region-configuration

[S2-mst-region]quit

开启S2的S0/0/23和S3的E0/0/23端口。

设置S2，S3之间的直连链路类为trunk链路，接收BPDU，并且允许所有VLAN通过。

[S2]interface GigabitEthernet 0/0/7

[S2-GigabitEthernet0/0/7]undo shutdown

[S2-GigabitEthernet0/0/7]port link-type trunk

[S2-GigabitEthernet0/0/7]port trunk all vlan all

[S2-GigabitEthernet0/0/7]bpdu enable

[S2-GigabitEthernet0/0/7]quit

[S3]interface GigabitEthernet0/0/7

[S3-GigabitEthernet0/0/7]undo shutdown

[S3-GigabitEthernet0/0/7]port link-type trunk

[S3-GigabitEthernet0/0/7]port trunk allow-pass vlan all

[S3-GigabitEthernet0/0/7]bpdu enable

[S3-GigabitEthernet0/0/7]quit

删除S4上的MSTP配置，并在S4上使能STP，

[S4]undo stp region-configuration

[S4]stp mode stp

配置完成，查看STP基本信息。

[S1]**display stp brief**

MSTID Port Role STP State Protection

0 GigabitEthernet0/0/10 DESI FORWARDING NONE

0 GigabitEthernet0/0/13 DESI FORWARDING NONE

1 GigabitEthernet0/0/10 DESI FORWARDING NONE

1 GigabitEthernet0/0/13 DESI FORWARDING NONE

2 GigabitEthernet0/0/10 DESI FORWARDING NONE

2 GigabitEthernet0/0/13 DESI FORWARDING NONE

[S2]**display stp brief**

MSTID Port Role STP State Protection

0 GigabitEthernet0/0/6 DESI FORWARDING NONE

0 GigabitEthernet0/0/7 DESI FORWARDING NONE

0 GigabitEthernet0/0/10 ROOT FORWARDING NONE

1 GigabitEthernet0/0/6 DESI FORWARDING NONE

1 GigabitEthernet0/0/7 DESI FORWARDING NONE

1 GigabitEthernet0/0/10 ROOT FORWARDING NONE

2 GigabitEthernet0/0/6 DESI FORWARDING NONE

2 GigabitEthernet0/0/7 DESI FORWARDING NONE

2 GigabitEthernet0/0/10 ROOT FORWARDING NONE

[S3]**display stp brief**

MSTID Port Role STP State Protection

0 GigabitEthernet0/0/1 DESI FORWARDING NONE

0 GigabitEthernet0/0/7 ALTE DISCARDING NONE

0 GigabitEthernet0/0/13 ROOT FORWARDING NONE

1 GigabitEthernet0/0/1 DESI FORWARDING NONE

1 GigabitEthernet0/0/7 ALTE DISCARDING NONE

1 GigabitEthernet0/0/13 ROOT FORWARDING NONE

2 GigabitEthernet0/0/1 DESI FORWARDING NONE

2 GigabitEthernet0/0/7 ALTE DISCARDING NONE

2 GigabitEthernet0/0/13 ROOT FORWARDING NONE

[S4]**display stp brief**

MSTID Port Role STP State Protection

0 GigabitEthernet0/0/1 ROOT FORWARDING NONE

0 GigabitEthernet0/0/6 ALTE DISCARDING NONE

运行STP的S4和运行MSTP的S1、S2、S3中的实例0共同计算CIST。此时S1为CIST的总根。

配置S4优先级为4096，使其成为CIST的总根，

[S4]stp priority 4096

查看STP基本信息。

[S1]**display stp brief**

MSTID Port Role STP State Protection

0 GigabitEthernet0/0/10 ROOT FORWARDING NONE

0 GigabitEthernet0/0/13 DESI FORWARDING NONE

1 GigabitEthernet0/0/10 DESI FORWARDING NONE

1 GigabitEthernet0/0/13 DESI FORWARDING NONE

2 GigabitEthernet0/0/10 DESI FORWARDING NONE

2 GigabitEthernet0/0/13 DESI FORWARDING NONE

[S2]**display stp brief**

MSTID Port Role STP State Protection

0 GigabitEthernet0/0/6 ROOT FORWARDING NONE

0 GigabitEthernet0/0/7 DESI FORWARDING NONE

0 GigabitEthernet0/0/10 DESI FORWARDING NONE

1 GigabitEthernet0/0/6 MAST FORWARDING NONE

1 GigabitEthernet0/0/7 DESI FORWARDING NONE

1 GigabitEthernet0/0/10 ROOT FORWARDING NONE

2 GigabitEthernet0/0/6 MAST FORWARDING NONE

2 GigabitEthernet0/0/7 DESI FORWARDING NONE

2 GigabitEthernet0/0/10 ROOT FORWARDING NONE

[S3]**display stp brief**

MSTID Port Role STP State Protection

0 GigabitEthernet0/0/1 ALTE DISCARDING NONE

0 GigabitEthernet0/0/7 ROOT FORWARDING NONE

0 GigabitEthernet0/0/13 ALTE DISCARDING NONE

1 GigabitEthernet0/0/1 ALTE DISCARDING NONE

1 GigabitEthernet0/0/7 ALTE DISCARDING NONE

1 GigabitEthernet0/0/13 ROOT FORWARDING NONE

2 GigabitEthernet0/0/1 ALTE DISCARDING NONE

2 GigabitEthernet0/0/7 ALTE DISCARDING NONE

2 GigabitEthernet0/0/13 ROOT FORWARDING NONE

[S4]**display stp brief**

MSTID Port Role STP State Protection

0 GigabitEthernet0/0/1 DESI FORWARDING NONE

0 GigabitEthernet0/0/6 DESI FORWARDING NONE

此时S4成为了CIST的总根，S4上的端口都是指定端口。

1. 配置指定端口保护

在S4的接口E0/0/1和E0/0/6上配置指定端口保护，

[S4]interface GigabitEthernet0/0/1

[S4-GigabitEthernet0/0/1]stp root-protection

[S4-GigabitEthernet0/0/1]quit

[S4]interface GigabitEthernet0/0/6

[S4-GigabitEthernet0/0/6]stp root-protection

[S4-GigabitEthernet0/0/6]quit

查看此时S4的STP基本信息，

[S4]display stp brief

MSTID Port Role STP State Protection

0 GigabitEthernet0/0/1 DESI FORWARDING ROOT

0 GigabitEthernet0/0/6 DESI DISCARDING ROOT

配置S2在实例0中的优先级为0，模拟抢占CIST根交换机。

[S2]stp instance 0 priority 0

查看S2，S4上的STP信息。

[S2]display stp brief

MSTID Port Role STP State Protection

0 GigabitEthernet0/0/6 DESI LEARNING NONE

0 GigabitEthernet0/0/7 DESI FORWARDING NONE

0 GigabitEthernet0/0/10 DESI FORWARDING NONE

1 GigabitEthernet0/0/6 DESI LEARNING NONE

1 GigabitEthernet0/0/7 DESI LEARNING NONE

1 GigabitEthernet0/0/10 ROOT FORWARDING NONE

2 GigabitEthernet0/0/6 DESI LEARNING NONE

2 GigabitEthernet0/0/7 DESI LEARNING NONE

2 GigabitEthernet0/0/10 ROOT FORWARDING NONE

[S4]display stp brief

MSTID Port Role STP State Protection

0 GigabitEthernet0/0/1 DESI DISCARDING ROOT

0 GigabitEthernet0/0/6 DESI DISCARDING ROOT

此时S4上的 端口状态进入Discarding状态，不转发报文。说明此时S4上的端口角色并没有变化，仍然是根交换机。

删除S2上的实例0优先级配置。

[S2]undo stp instance 0 priority

查看S2，S4上的STP信息。

[S2]display stp brief

MSTID Port Role STP State Protection

0 GigabitEthernet0/0/6 ROOT FORWARDING NONE

0 GigabitEthernet0/0/7 DESI FORWARDING NONE

0 GigabitEthernet0/0/10 DESI FORWARDING NONE

1 GigabitEthernet0/0/6 MAST FORWARDING NONE

1 GigabitEthernet0/0/7 DESI FORWARDING NONE

1 GigabitEthernet0/0/10 ROOT FORWARDING NONE

2 GigabitEthernet0/0/6 MAST FORWARDING NONE

2 GigabitEthernet0/0/7 DESI FORWARDING NONE

2 GigabitEthernet0/0/10 ROOT FORWARDING NONE

[S4]display stp brief

MSTID Port Role STP State Protection

0 GigabitEthernet0/0/1 DESI FORWARDING ROOT

0 GigabitEthernet0/0/6 DESI FORWARDING ROOT

当在足够长的时间内（Max Age，默认20秒）没有收到更优的配置消息时，端口会恢复原来的正常状态，进入转发状态。

1. 配置边缘端口保护

开启S2的G0/0/9接口，

[S2]interface GigabitEthernet 0/0/9

[S2-GigabitEthernet0/0/9]undo shutdown

[S2-GigabitEthernet0/0/9]quit

将S1的接口G0/0/9配置成边缘端口，并在全局模式下开启边缘端口的保护功能。

[S1]interface GigabitEthernet 0/0/9

[S1-GigabitEthernet0/0/9]undo shutdown

[S1-GigabitEthernet0/0/9]stp edged-port enable

[S1-GigabitEthernet0/0/9]quit

[S1]stp bpdu-protection

查看S1上的STP信息。

[S1]display stp interface GigabitEthernet 0/0/9 brief

MSTID Port Role STP State Protection

0 GigabitEthernet0/0/9 DESI FORWARDING BPDU

开启S1的G0/0/9接口，使边缘端口端口能收到BPDU，模拟交换机受到攻击。

[S1]interface GigabitEthernet 0/0/9

[S1-GigabitEthernet0/0/9]undo shutdown

[S1-GigabitEthernet0/0/9]quit

观察S1上的现象。

Dec 21 2011 08:39:51-05:13 S1 %%01IFNET/4/IF\_STATE(l)[3]:Interface GigabitEthernet0/0/9 has turned into UP state.

Dec 21 2011 08:39:51-05:13 S1 %%01MSTP/4/BPDU\_PROTECTION(l)[4]:This edged-port GigabitEthernet0/0/9 that enabled BPDU-Protection will be shutdown, because it received BPDU packet!

Dec 21 2011 08:39:52-05:13 S1 %%01IFNET/4/IF\_STATE(l)[5]:Interface GigabitEthernet0/0/9 has turned into DOWN state.

配置边缘端口保护之后，一旦启用了边缘端口，使其收到BPDU，会自动关闭该端口。

1. 配置环路保护

在S3的接口E0/0/23上配置环路保护。

[S3]interface GigabitEthernet0/0/7

[S3-GigabitEthernet0/0/7]stp loop-protection

[S3-GigabitEthernet0/0/7]quit

查看S3上该接口的STP信息。

[S3]display stp interface Ethernet 0/0/7 brief

MSTID Port Role STP State Protection

0 GigabitEthernet0/0/7 ROOT FORWARDING LOOP

1 GigabitEthernet0/0/7 ALTE DISCARDING LOOP

2 GigabitEthernet0/0/7 ALTE DISCARDING LOOP

1. 配置TC-BPDU保护

在S1上开启对TC类型BPDU报文的保护功能。

[S1]stp tc-protection

## **附加实验: 思考并验证**

思考不同交换机上的MSTP域名一致，修订版本号不同会不会产生影响。

思考在步骤四中，如果改变S3中实例1上的优先级为0，则此时四台交换机端口的状态会产生哪些变化。

## **最终设备配置**

<S1>**display current-configuration**

#

!Software Version V200R008C00SPC500

sysname S1

#

vlan batch 3 to 8

#

stp bpdu-protection

stp tc-protection

#

stp region-configuration

region-name RG1

revision-level 1

instance 1 vlan 3 to 5

instance 2 vlan 6 to 8

active region-configuration

#

interface GigabitEthernet0/0/9

shutdown

stp edged-port enable

#

interface GigabitEthernet0/0/10

port link-type trunk

port trunk allow-pass vlan 2 to 4094

#

interface GigabitEthernet0/0/13

port link-type trunk

port trunk allow-pass vlan 2 to 4094

#

return

<S2>**display current-configuration**

#

!Software Version V200R008C00SPC500

sysname S2

#

vlan batch 3 to 8

#

stp region-configuration

region-name RG1

revision-level 1

instance 1 vlan 3 to 5

instance 2 vlan 6 to 8

active region-configuration

#

interface GigabitEthernet0/0/6

port link-type trunk

port trunk allow-pass vlan 2 to 4094

#

interface GigabitEthernet0/0/7

port link-type trunk

port trunk allow-pass vlan 2 to 4094

#

interface GigabitEthernet0/0/9

#

interface GigabitEthernet0/0/10

port link-type trunk

port trunk allow-pass vlan 2 to 4094

#

return

<S3>**display current-configuration**

#

!Software Version V100R006C05

sysname S3

#

vlan batch 3 to 8

#

stp region-configuration

region-name RG1

revision-level 1

instance 1 vlan 3 to 5

instance 2 vlan 6 to 8

active region-configuration

#

interface GigabitEthernet0/0/1

port link-type trunk

port trunk allow-pass vlan 2 to 4094

#

interface GigabitEthernet0/0/7

port link-type trunk

port trunk allow-pass vlan 2 to 4094

stp loop-protection

#

interface GigabitEthernet0/0/13

port link-type trunk

port trunk allow-pass vlan 2 to 4094

#

return

<S4>**display current-configuration**

#

!Software Version V100R006C05

sysname S4

#

vlan batch 3 to 8 30

#

stp mode stp

stp instance 0 priority 4096

#

interface Vlanif30

ip address 100.100.100.8 255.255.255.0

#

interface GigabitEthernet0/0/1

port link-type trunk

port trunk allow-pass vlan 2 to 4094

stp root-protection

undo ntdp enable

undo ndp enable

#

interface GigabitEthernet0/0/6

port link-type trunk

port trunk allow-pass vlan 2 to 4094

stp root-protection

undo ntdp enable

undo ndp enable

#

interface GigabitEthernet0/0/7

port link-type access

port default vlan 30

undo ntdp enable

undo ndp enable

bpdu disable

#

interface GigabitEthernet0/0/14

shutdown

undo ntdp enable

undo ndp enable

bpdu disable

#

Return