深 圳 大 学 实 验 报 告

课程名称：计算机网络

实验项目名称：实验 7　IPv6 隧道

学院：计算机与软件学院

专业：软件工程

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实验时间：2023 年 5 月 30 日至 2023 年 6 月 20 日

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教务处制

实验目的：

1. 学习安装与使用华为 eNSP 网络仿真软件
2. 理解 IPv6 over IPv4 的原理
3. 掌握 IPv6 over IPv4 手工隧道的配置方法
4. 掌握 OSPF 路由的配置方法
5. 掌握 IPv6 静态路由的配置方法

实验环境：

Windows 系统
eNSP 网络仿真软件

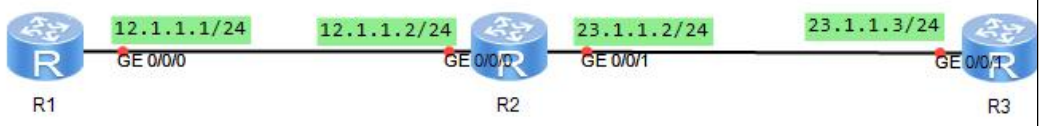
实验内容：

1. 建立三路由拓扑
2. OSPF 路由配置
3. 创建虚接口
4. 创建 IPv6 虚接口
5. 创建 IPv6 over IPv4 隧道
6. 配置 IPv6 静态路由

实验步骤：

一、建立三路由拓扑

选择 AR1220 型号路由器，拖动至主页面创建 3 个路由器；选择 Copper 型号线，连接路由器 R1 和 R2、R2 和 R3 如下图所示。



选择添加文本和显示所有接口。

右击启动路由器，输入 system-view 进入系统试图，使用 sysname R1 可以重命名路由器。

```
<Huawei>system-view
Enter system view, return user view with Ctrl+Z.
[Huawei]sysname R1
[R1]
```

为每个路由器配置 IPv4 地址。

```
[R1]interface GigabitEthernet 0/0/0
[R1-GigabitEthernet0/0/0]ip address 12.1.1.1 255.255.255.0
[R1-GigabitEthernet0/0/0]
```

```
[Huawei]sysname R2
[R2]interface GigabitEthernet 0/0/0
[R2-GigabitEthernet0/0/0]ip address 12.1.1.2 255.255.255.0
May 30 2023 10:28:05-08:00 R2 %%01IFNET/4/LINK_STATE(l)[1]:The line protocol I
on the interface GigabitEthernet0/0/0 has entered the UP state.
[R2-GigabitEthernet0/0/0]
```

```
[R2]interface GigabitEthernet 0/0/1
[R2-GigabitEthernet0/0/1]ip address 23.1.1.2 255.255.255.0
```

R1 ping R2

```
[R1-GigabitEthernet0/0/0]ping 12.1.1.2
  PING 12.1.1.2: 56  data bytes, press CTRL_C to break
    Reply from 12.1.1.2: bytes=56 Sequence=1 ttl=255 time=80 ms
    Reply from 12.1.1.2: bytes=56 Sequence=2 ttl=255 time=30 ms
    Reply from 12.1.1.2: bytes=56 Sequence=3 ttl=255 time=10 ms
    Reply from 12.1.1.2: bytes=56 Sequence=4 ttl=255 time=10 ms
    Reply from 12.1.1.2: bytes=56 Sequence=5 ttl=255 time=10 ms

  --- 12.1.1.2 ping statistics ---
    5 packet(s) transmitted
    5 packet(s) received
    0.00% packet loss
    round-trip min/avg/max = 10/28/80 ms

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

R2 ping R1

```
[R2-GigabitEthernet0/0/0]ping 12.1.1.1
  PING 12.1.1.1: 56  data bytes, press CTRL_C to break
    Reply from 12.1.1.1: bytes=56 Sequence=1 ttl=255 time=20 ms
    Reply from 12.1.1.1: bytes=56 Sequence=2 ttl=255 time=30 ms
    Reply from 12.1.1.1: bytes=56 Sequence=3 ttl=255 time=20 ms
    Reply from 12.1.1.1: bytes=56 Sequence=4 ttl=255 time=20 ms
    Reply from 12.1.1.1: bytes=56 Sequence=5 ttl=255 time=10 ms

  --- 12.1.1.1 ping statistics ---
    5 packet(s) transmitted
    5 packet(s) received
    0.00% packet loss
    round-trip min/avg/max = 10/20/30 ms

[R2-GigabitEthernet0/0/0]
```

R3 配置如下：

```
[R3]interface GigabitEthernet 0/0/1
[R3-GigabitEthernet0/0/1]ip address 23.1.1.3 255.255.255.0
May 30 2023 10:30:45-08:00 R3 %%01IFNET/4/LINK_STATE(l)[1]:The line protocol IP
on the interface GigabitEthernet0/0/1 has entered the UP state.
[R3-GigabitEthernet0/0/1]
```

R1 ping R3，无法 ping 通，因为他们分属于两个不同的网络。

```
[R1-GigabitEthernet0/0/0]ping 23.1.1.3
  PING 23.1.1.3: 56  data bytes, press CTRL_C to break
    Request time out
    Request time out
    Request time out
    Request time out
    Request time out

  --- 23.1.1.3 ping statistics ---
    5 packet(s) transmitted
    0 packet(s) received
    100.00% packet loss

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

二、OSFP 路由配置

配置路由使 R1 和 R3 互通：

打印路由表查看信息：

```
[R1]display ip routing-table
Route Flags: R - relay, D - download to fib
------------------------------------------------------------------------------
Routing Tables: Public
         Destinations : 7        Routes : 7

Destination/Mask    Proto   Pre  Cost      Flags NextHop         Interface

        12.1.1.0/24  Direct  0    0           D   12.1.1.1        GigabitEthernet
0/0/0
        12.1.1.1/32  Direct  0    0           D   127.0.0.1       GigabitEthernet
0/0/0
      12.1.1.255/32  Direct  0    0           D   127.0.0.1       GigabitEthernet
0/0/0
       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

[R1]
```

创建并运行 OSPF 进程，然后打印其路由表信息进行查看

```
[R1]ospf 2
[R1-ospf-2]display ospf 2 routing

        OSPF Process 2 with Router ID 12.1.1.1
               Routing Tables

 Total Nets: 0
 Intra Area: 0  Inter Area: 0  ASE: 0  NSSA: 0
```

Area 命令创建 OSPF 区域，进入 OSPF 区域视图；然后使用 network 命令指定运行 OSPF 协议的接口和接口所属的区域。

```
[R1-ospf-2]area 0
[R1-ospf-2-area-0.0.0.0]network 12.1.1.0 0.0.0.255
[R1-ospf-2-area-0.0.0.0]
```

按同样的步骤配置 R2 和 R3。

```
[R2]ospf 2
[R2-ospf-2]area 0
[R2-ospf-2-area-0.0.0.0]network 12.1.1.0 0.0.0.255
[R2-ospf-2-area-0.0.0.0]
```

```
[R2-ospf-2-area-0.0.0.0]
May 30 2023 10:37:30-08:00 R2 %%01OSPF/4/NBR_CHANGE_E(1)[5]:Neighbor changes e
nt: neighbor status changed. (ProcessId=512, NeighborAddress=1.1.1.12, Neighbo
vent=LoadingDone, NeighborPreviousState=Loading, NeighborCurrentState=Full)
[R2-ospf-2-area-0.0.0.0]network 23.1.1.0 0.0.0.255
[R2-ospf-2-area-0.0.0.0]
```

```
[R3]ospf 2
[R3-ospf-2]area 0
[R3-ospf-2-area-0.0.0.0]network 23.1.1.0 0.0.0.255
[R3-ospf-2-area-0.0.0.0]
```

尝试 R1 ping R3，ping 通

```
[R1-GigabitEthernet0/0/0]ping 23.1.1.3
  PING 23.1.1.3: 56  data bytes, press CTRL_C to break
    Reply from 23.1.1.3: bytes=56 Sequence=1 ttl=254 time=30 ms
    Reply from 23.1.1.3: bytes=56 Sequence=2 ttl=254 time=40 ms
    Reply from 23.1.1.3: bytes=56 Sequence=3 ttl=254 time=20 ms
    Reply from 23.1.1.3: bytes=56 Sequence=4 ttl=254 time=20 ms
    Reply from 23.1.1.3: bytes=56 Sequence=5 ttl=254 time=20 ms

  --- 23.1.1.3 ping statistics ---
    5 packet(s) transmitted
    5 packet(s) received
    0.00% packet loss
    round-trip min/avg/max = 20/26/40 ms

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

三、创建虚接口

创建 LoopBack 虚接口并分配 ip 地址

```
[R1]interface LoopBack 0
[R1-LoopBack0]ip address 1.1.1.1 255.255.255.255
[R1-LoopBack0]
```

```
[R3]interface LoopBack 0
[R3-LoopBack0]ip address 3.3.3.3 255.255.255.255
[R3-LoopBack0]
```

R1 尝试 ping R3 的 LoopBack 0 接口，不能 ping 通

```
[R1-LoopBack0]ping 3.3.3.3
  PING 3.3.3.3: 56  data bytes, press CTRL_C to break
    Request time out
    Request time out
    Request time out
    Request time out
    Request time out

  --- 3.3.3.3 ping statistics ---
    5 packet(s) transmitted
    0 packet(s) received
    100.00% packet loss

[R1-LoopBack0]
```

配置 ospf 使其 ping 通：

```
[R1]ospf 2
[R1-ospf-2]area 0
[R1-ospf-2-area-0.0.0.0]network 1.1.1.1 0.0.0.0
```

```
[R3]ospf 2
[R3-ospf-2]area 0
[R3-ospf-2-area-0.0.0.0]network 3.3.3.3 0.0.0.0
[R3-ospf-2-area-0.0.0.0]
```

再次尝试 R1 ping R3 的 LoopBack 0 接口，ping 通：

```
[R1-ospf-2-area-0.0.0.0]ping 3.3.3.3
  PING 3.3.3.3: 56  data bytes, press CTRL_C to break
    Reply from 3.3.3.3: bytes=56 Sequence=1 ttl=254 time=40 ms
    Reply from 3.3.3.3: bytes=56 Sequence=2 ttl=254 time=30 ms
    Reply from 3.3.3.3: bytes=56 Sequence=3 ttl=254 time=20 ms
    Reply from 3.3.3.3: bytes=56 Sequence=4 ttl=254 time=20 ms
    Reply from 3.3.3.3: bytes=56 Sequence=5 ttl=254 time=30 ms

  --- 3.3.3.3 ping statistics ---
    5 packet(s) transmitted
    5 packet(s) received
    0.00% packet loss
    round-trip min/avg/max = 20/28/40 ms

[R1-ospf-2-area-0.0.0.0]
```

四、创建 IPv6 虚接口测试 R1 和 R3 之间 IPv6 的连通性

创建虚接口、在接口上使能 IPv6 功能，配置接口的全球单播地址：

```
[R1]ipv6
[R1]interface LoopBack 1
[R1-LoopBack1]ipv6 enable
[R1-LoopBack1]ipv6 address 2001:1::1 64
[R1-LoopBack1]
```

```
[R3]ipv6
[R3]interface LoopBack 1
[R3-LoopBack1]ipv6 enable
[R3-LoopBack1]ipv6 address 2001:3::3/64
[R3-LoopBack1]
```

R1 尝试 ping 自己的 LoopBack1，ping 通

```
[R1]ping ipv6 2001:1::1
  PING 2001:1::1 : 56  data bytes, press CTRL_C to break
    Reply from 2001:1::1
    bytes=56 Sequence=1 hop limit=64  time = 10 ms
    Reply from 2001:1::1
    bytes=56 Sequence=2 hop limit=64  time = 1 ms
    Reply from 2001:1::1
    bytes=56 Sequence=3 hop limit=64  time = 1 ms
    Reply from 2001:1::1
    bytes=56 Sequence=4 hop limit=64  time = 1 ms
    Reply from 2001:1::1
    bytes=56 Sequence=5 hop limit=64  time = 1 ms

  --- 2001:1::1 ping statistics ---
    5 packet(s) transmitted
    5 packet(s) received
    0.00% packet loss
    round-trip min/avg/max = 1/2/10 ms

[R1]
```

R1 尝试 ping R3 的 LoopBack1，不通，因为没有 IPv6 over IPv4 隧道。

```
[R1]ping ipv6 2001:3::3
  PING 2001:3::3 : 56  data bytes, press CTRL_C to break
    Request time out
    Request time out
    Request time out
    Request time out
    Request time out

  --- 2001:3::3 ping statistics ---
    5 packet(s) transmitted
    0 packet(s) received
    100.00% packet loss
    round-trip min/avg/max = 0/0/0 ms

[R1]
```

五、创建 IPv6 over IPv4 隧道

进入 tunnel 接口视图，配置 IPv6 地址。

```
[R1]interface tunnel 0/0/0
[R1-Tunnel0/0/0]ipv6 enable
[R1-Tunnel0/0/0]ipv6 address 2001:13::1 64
[R1-Tunnel0/0/0]
```

配置 tunnel 接口的隧道协议、源地址或源接口以及目的地址。

```
[R1-Tunnel0/0/0]tunnel-protocol ipv6-ipv4
[R1-Tunnel0/0/0]source LoopBack 0
[R1-Tunnel0/0/0]destination 3.3.3.3
May 30 2023 11:11:35-08:00 R1 IPV6/2/IF_IPV6CHANGE:OID 16777216.50331648.10066
96.16777216.33554432.16777216.922746880.33554432.0.16777216 The status of the
v6 Interface changed. (IfIndex=251658240, IfDescr=HUAWEI, AR Series, Tunnel0/0
 Interface, IfOperStatus=16777216, IfAdminStatus=16777216)
[R1-Tunnel0/0/0]
May 30 2023 11:11:35-08:00 R1 %%01IFNET/4/LINK_STATE(l)[0]:The line protocol I
6 on the interface Tunnel0/0/0 has entered the UP state.
[R1-Tunnel0/0/0]
```

同样的方法对 R3 进行配置

```
[R3]interface tunnel 0/0/0
[R3-Tunnel0/0/0]ipv6 enable
[R3-Tunnel0/0/0]ipv6 address 2001:13::3 64
[R3-Tunnel0/0/0]tunnel-protocol ipv6-ipv4
[R3-Tunnel0/0/0]source LoopBack 0
```

```
[R3-Tunnel0/0/0]destination 1.1.1.1
[R3-Tunnel0/0/0]
```

R1 尝试 ping 通 R3 的 tunnel0/0/0，ping 通

```
[R1-Tunnel0/0/0]ping ipv6 2001:13::3
  PING 2001:13::3 : 56  data bytes, press CTRL_C to break
    Reply from 2001:13::3
    bytes=56 Sequence=1 hop limit=64  time = 40 ms
    Reply from 2001:13::3
    bytes=56 Sequence=2 hop limit=64  time = 30 ms
    Reply from 2001:13::3
    bytes=56 Sequence=3 hop limit=64  time = 30 ms
    Reply from 2001:13::3
    bytes=56 Sequence=4 hop limit=64  time = 40 ms
    Reply from 2001:13::3
    bytes=56 Sequence=5 hop limit=64  time = 30 ms

  --- 2001:13::3 ping statistics ---
    5 packet(s) transmitted
    5 packet(s) received
    0.00% packet loss
    round-trip min/avg/max = 30/34/40 ms

[R1-Tunnel0/0/0]
```

R1 尝试 ping R3 的 LoopBack1，不通，因为路由器不知道怎么转发去往 R3 LoopBack1 的分组。

```
[R1-Tunnel0/0/0]ping ipv6 2001:3::3
  PING 2001:3::3 : 56  data bytes, press CTRL_C to break
    Request time out
    Request time out
    Request time out
    Request time out
    Request time out

  --- 2001:3::3 ping statistics ---
    5 packet(s) transmitted
    0 packet(s) received
    100.00% packet loss
    round-trip min/avg/max = 0/0/0 ms

[R1-Tunnel0/0/0]
```

六、配置 IPv6 静态路由

配置静态路由

```
[R1]ipv6 route-static 2001:3:: 64 Tunnel0/0/0
```

再次尝试 R1 ping R3 的 LoopBack1，ping 通。

```
[R1]ping ipv6 2001:3::3
  PING 2001:3::3 : 56  data bytes, press CTRL_C to break
    Reply from 2001:3::3
    bytes=56 Sequence=1 hop limit=64  time = 20 ms
    Reply from 2001:3::3
    bytes=56 Sequence=2 hop limit=64  time = 30 ms
    Reply from 2001:3::3
    bytes=56 Sequence=3 hop limit=64  time = 30 ms
    Reply from 2001:3::3
    bytes=56 Sequence=4 hop limit=64  time = 20 ms
    Reply from 2001:3::3
    bytes=56 Sequence=5 hop limit=64  time = 30 ms

  --- 2001:3::3 ping statistics ---
    5 packet(s) transmitted
    5 packet(s) received
    0.00% packet loss
    round-trip min/avg/max = 20/26/30 ms

[R1]
```

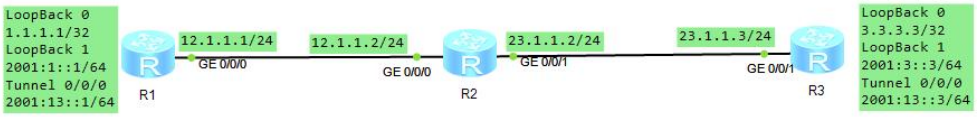
对 R3 的静态路由进行同样的配置。可以使 R3 成功 ping 通 R1 的 LoopBack1。

```
[R3]ipv6 route-static 2001:1:: 64 Tunnel0/0/0
[R3]ping ipv6 2001:1::1
  PING 2001:1::1 : 56  data bytes, press CTRL_C to break
    Reply from 2001:1::1
    bytes=56 Sequence=1 hop limit=64  time = 1 ms
    Reply from 2001:1::1
    bytes=56 Sequence=2 hop limit=64  time = 1 ms
    Reply from 2001:1::1
    bytes=56 Sequence=3 hop limit=64  time = 1 ms
    Reply from 2001:1::1
    bytes=56 Sequence=4 hop limit=64  time = 1 ms
    Reply from 2001:1::1
    bytes=56 Sequence=5 hop limit=64  time = 1 ms

  --- 2001:1::1 ping statistics ---
    5 packet(s) transmitted
    5 packet(s) received
    0.00% packet loss
    round-trip min/avg/max = 1/1/1 ms

[R3]
```

实验过程所使用的三路由器拓扑完整接口信息如下：



实验小结：

1. 通过本次实验，对如何利用 eNSP 工具建立三路由拓扑以及实现路由之间的互通进行了学习。
2. 对于位于不同网络的路由，要实现它们的互通，需要使用 OSPF 对路由进行配置；对于 LoopBack 虚接口，需要建立 IPv6 over IPv4 隧道，使路由器彼此之间可以互通其 IPv6 地址。
3. 通过对上述过程的实现，学会了 IPv6 over IPv4 手工隧道、OSPF 路由和 IPv6 静态路由的配置方法。

指导教师批阅意见：   **成绩评定：**   **指导教师签字：** 年　　月　　日
备注：