厦門大學

信息学院软件工程系

《计算机网络》实验报告

题　　目　实验 7　IPv6 网络基础

班　　级　数字媒体技术 2022 级 1 班

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填写说明

1、本文件为 Word 模板文件，建议使用 Microsoft Word 2021 打开，在可填写的区域中如实填写；

2、填表时勿改变字体字号，保持排版工整，打印为 PDF 文件提交；

3、文件总大小尽量控制在 1MB 以下，最大勿超过 5MB；

4、应将材料清单上传在代码托管平台上；

5、在实验课结束 14 天内，按原文件发送至课程 FTP 指定位置。

1 实验目的

3
学会 eNSP 的安装、学习和使用
7.1
1. 掌握网络设备静态 IPv6 地址配置。
2. 掌握 IPv6 地址无状态自动配置的应用。
3. 掌握通过 DHCPv6 部署 IPv6 地址配置自动化。
4. 掌握基本的 IPv6 网络连通性测试方法

7.2
1. 掌握数据报文捕获及分析方法。
2. 理解 RA 报文及无状态地址自动配置过程。
3. 理解 DAD 地址冲突检测机制工作过程。
4. 理解 IPv6 网络中的地址解析过程。
5. 分析 Ping 与 Tracert 应用所使用的 ICMPv6 报文及工作原理。
6. 理解 IPv6 PMTUD 机制及其工作原理。

2 实验环境

操作系统：Win11

3 实验结果

3 数通模拟器的安装和使用

建立拓扑

启动后，进行路由器的配置

```
<Huawei>sys
<Huawei>system-view
Enter system view, return user view with Ctrl+Z.
[Huawei]inte
[Huawei]interface Giga
[Huawei]interface GigabitEthernet 0/0/0
[Huawei-GigabitEthernet0/0/0]ip a
[Huawei-GigabitEthernet0/0/0]ip accountin
[Huawei-GigabitEthernet0/0/0]ip accounting
[Huawei-GigabitEthernet0/0/0]ip accounting
[Huawei-GigabitEthernet0/0/0]ip add
[Huawei-GigabitEthernet0/0/0]ip address 192.168.1.254 24
Oct 14 2024 20:28:51-08:00 Huawei %%01IFNET/4/LINK_STATE(l)[1]:The line protocol
 IP on the interface GigabitEthernet0/0/0 has entered the UP state.
[Huawei-GigabitEthernet0/0/0]
```

配置主机

Ping 指令结果

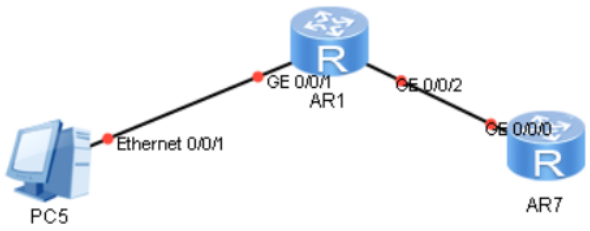
```
Ping 192.168.1.254: 32 data bytes, Press Ctrl_C to break
From 192.168.1.254: bytes=32 seq=1 ttl=255 time=31 ms
From 192.168.1.254: bytes=32 seq=2 ttl=255 time=16 ms
From 192.168.1.254: bytes=32 seq=3 ttl=255 time=16 ms
From 192.168.1.254: bytes=32 seq=4 ttl=255 time=15 ms
From 192.168.1.254: bytes=32 seq=5 ttl=255 time<1 ms

--- 192.168.1.254 ping statistics ---
  5 packet(s) transmitted
  5 packet(s) received
  0.00% packet loss
  round-trip min/avg/max = 0/15/31 ms

PC>
```

7.1 IPv6 地址配置实验

创建拓扑



1. 完成 R1 的 IPv6 配置

```
<Huawei>system-view
Enter system view, return user view with Ctrl+Z.
[Huawei]sysn
[Huawei]sysname R1
[R1]ipv6
[R1]inter
[R1]interface Giga
[R1]interface GigabitEthernet 0/0/1
[R1-GigabitEthernet0/0/1]ipv6 enable
[R1-GigabitEthernet0/0/1]ipv6 address FC00:1000::1 64
[R1-GigabitEthernet0/0/1]quit
[R1]inter
[R1]interface Giga
[R1]interface GigabitEthernet 0/0/2
[R1-GigabitEthernet0/0/2]ipv6 en
[R1-GigabitEthernet0/0/2]ipv6 enable
[R1-GigabitEthernet0/0/2]ipv6 addr
[R1-GigabitEthernet0/0/2]ipv6 address FC00:14::1 64
[R1-GigabitEthernet0/0/2]quit
[R1]display ipv6 interface brief
*down: administratively down
(l): loopback
(s): spoofing
Interface                  Physical              Protocol
GigabitEthernet0/0/1       down                  down
[IPv6 Address] FC00:1000::1 [TENTATIVE]
GigabitEthernet0/0/2       down                  down
[IPv6 Address] FC00:14::1 [TENTATIVE]
[R1]
```

2. 完成 IPv6 地址五状态自动配置

激活使能设备发布 RA 报文功能

```
[R1]interface GigabitEthernet 0/0/2
[R1-GigabitEthernet0/0/2]undo ipv6 nd ra halt
```

配置 R4

```
<Huawei>system-view
Enter system view, return user view with Ctrl+Z.
[Huawei]sysn
[Huawei]sysname R4
[R4]ipv6
[R4]inter
[R4]interface Gig
[R4]interface GigabitEthernet 0/0/0
[R4-GigabitEthernet0/0/0]ipv6 en
[R4-GigabitEthernet0/0/0]ipv6 enable
[R4-GigabitEthernet0/0/0]ipv6 addr
[R4-GigabitEthernet0/0/0]ipv6 address auto gl
[R4-GigabitEthernet0/0/0]ipv6 address auto global def
[R4-GigabitEthernet0/0/0]ipv6 address auto global default
[R4-GigabitEthernet0/0/0]
Oct 14 2024 21:05:09-08:00 R4 IPV6/2/IF_IPV6CHANGE:OID 16777216.50331648.1006632
96.16777216.33554432.16777216.922746880.33554432.0.16777216 The status of the IP
v6 Interface changed. (IfIndex=50331648, IfDescr=HUAWEI, AR Series, GigabitEther
net0/0/0 Interface, IfOperStatus=16777216, IfAdminStatus=16777216)
[R4-GigabitEthernet0/0/0]
Oct 14 2024 21:05:09-08:00 R4 %%01IFNET/4/LINK_STATE(l)[1]:The line protocol IPv
6 on the interface GigabitEthernet0/0/0 has entered the UP state.
[R4-GigabitEthernet0/0/0]quit
[R4]dis
[R4]display ipv6
[R4]display ipv6 int
[R4]display ipv6 interface brief
*down: administratively down
(l): loopback
(s): spoofing
Interface                   Physical              Protocol
GigabitEthernet0/0/0        up                    up
[IPv6 Address] FC00:14::2E0:FCFF:FE9A:3E14
[R4]
```

```
[R4]display interface GigabitEthernet 0/0/0
GigabitEthernet0/0/0 current state : UP
Line protocol current state : DOWN
Description:HUAWEI, AR Series, GigabitEthernet0/0/0 Interface
Route Port,The Maximum Transmit Unit is 1500
Internet protocol processing : disabled
IP Sending Frames' Format is PKTFMT_ETHNT_2, Hardware address is 00e0-fc9a-3e14
Last physical up time   : 2024-10-14 21:04:25 UTC-08:00
Last physical down time : 2024-10-14 21:04:22 UTC-08:00
Current system time: 2024-10-14 21:06:43-08:00
Port Mode: FORCE COPPER
Speed : 1000,  Loopback: NONE
Duplex: FULL,  Negotiation: ENABLE
Mdi   : AUTO
Last 300 seconds input rate 16 bits/sec, 0 packets/sec
Last 300 seconds output rate 8 bits/sec, 0 packets/sec
Input peak rate 248 bits/sec,Record time: 2024-10-14 21:04:37
Output peak rate 360 bits/sec,Record time: 2024-10-14 21:05:17

Input:  8 packets, 784 bytes
  Unicast:                0,  Multicast:                8
  Broadcast:              0,  Jumbo:                    0
  Discard:                0,  Total Error:              0

  CRC:                    0,  Giants:                   0
```

测试 R4 连接 R1

```
[R4]ping ipv6 fc00:14::1
  PING fc00:14::1 : 56  data bytes, press CTRL_C to break
    Reply from FC00:14::1
    bytes=56 Sequence=1 hop limit=64  time = 60 ms
    Reply from FC00:14::1
    bytes=56 Sequence=2 hop limit=64  time = 10 ms
    Reply from FC00:14::1
    bytes=56 Sequence=3 hop limit=64  time = 20 ms
    Reply from FC00:14::1
    bytes=56 Sequence=4 hop limit=64  time = 20 ms
    Reply from FC00:14::1
    bytes=56 Sequence=5 hop limit=64  time = 10 ms

  --- fc00:14::1 ping statistics ---
    5 packet(s) transmitted
    5 packet(s) received
    0.00% packet loss
    round-trip min/avg/max = 10/24/60 ms
```

3. 完成 DHCPv6 部署

```
<R1>system-view
Enter system view, return user view with Ctrl+Z.
[R1]dhcp en
[R1]dhcp enable
Info: The operation may take a few seconds. Please wait for a moment.done.
[R1]dhcpv6 poop pool1
           ^
Error: Unrecognized command found at '^' position.
[R1]dhcpv6 pool pool1
[R1-dhcpv6-pool-pool1]addre
[R1-dhcpv6-pool-pool1]address pre
[R1-dhcpv6-pool-pool1]address prefix fc00:1000::/64
[R1-dhcpv6-pool-pool1]exclu
[R1-dhcpv6-pool-pool1]excluded-address fc00:1000::1
[R1-dhcpv6-pool-pool1]quit
[R1]inter
[R1]interface Giga
[R1]interface GigabitEthernet 0/0/1
[R1-GigabitEthernet0/0/1]dh
[R1-GigabitEthernet0/0/1]dhcpv6 server pool1
[R1-GigabitEthernet0/0/1]undo ipv6 nd ra halt
[R1-GigabitEthernet0/0/1]ipv6 nd auto
[R1-GigabitEthernet0/0/1]ipv6 nd autoconfig mana
[R1-GigabitEthernet0/0/1]ipv6 nd autoconfig managed-address-flag
[R1-GigabitEthernet0/0/1]ipv6 nd auto
[R1-GigabitEthernet0/0/1]ipv6 nd autoconfig ot
[R1-GigabitEthernet0/0/1]ipv6 nd autoconfig other-flag
[R1-GigabitEthernet0/0/1]quit
```

4. 测试 IPv6 网络连通性

```
[R4]quit
<R4>ping ipv6 fc00:1000::2
  PING fc00:1000::2 : 56  data bytes, press CTRL_C to break
    Reply from FC00:1000::2
    bytes=56 Sequence=1 hop limit=254  time = 30 ms
    Reply from FC00:1000::2
    bytes=56 Sequence=2 hop limit=254  time = 30 ms
    Reply from FC00:1000::2
    bytes=56 Sequence=3 hop limit=254  time = 20 ms
    Reply from FC00:1000::2
    bytes=56 Sequence=4 hop limit=254  time = 20 ms
    Reply from FC00:1000::2
    bytes=56 Sequence=5 hop limit=254  time = 30 ms

  --- fc00:1000::2 ping statistics ---
    5 packet(s) transmitted
    5 packet(s) received
    0.00% packet loss
    round-trip min/avg/max = 20/26/30 ms
```

7.2 ICMPv6 与 NDP 实验

1. 完成 R2 的基础配置

```
<Huawei>sys
<Huawei>system-view
Enter system view, return user view with Ctrl+Z.
[Huawei]sysn
[Huawei]sysname R2
[R2]ipv
[R2]ipv6
[R2]inter
[R2]interface Giga
[R2]interface GigabitEthernet 0/0/0
[R2-GigabitEthernet0/0/0]ipv
[R2-GigabitEthernet0/0/0]ipv6 en
[R2-GigabitEthernet0/0/0]ipv6 enable
[R2-GigabitEthernet0/0/0]ipv
[R2-GigabitEthernet0/0/0]ipv6 addr
[R2-GigabitEthernet0/0/0]ipv6 address fc00:12::2 64
[R2-GigabitEthernet0/0/0]undo ip
Oct 14 2024 22:13:25-08:00 R2 IPV6/2/IF_IPV6CHANGE:OID 16777216.50331648.1006632
96.16777216.33554432.16777216.922746880.33554432.0.16777216 The status of the IP
v6 Interface changed. (IfIndex=50331648, IfDescr=HUAWEI, AR Series, GigabitEther
net0/0/0 Interface, IfOperStatus=16777216, IfAdminStatus=16777216)
[R2-GigabitEthernet0/0/0]undo ip
Oct 14 2024 22:13:25-08:00 R2 %%01IFNET/4/LINK_STATE(l)[2]:The line protocol IPv
6 on the interface GigabitEthernet0/0/0 has entered the UP state.
[R2-GigabitEthernet0/0/0]undo ipv
[R2-GigabitEthernet0/0/0]undo ipv6 nd ra ha
[R2-GigabitEthernet0/0/0]undo ipv6 nd ra halt
[R2-GigabitEthernet0/0/0]quit
[R2]
```

2. 观察 RA 报文与无状态地址自动配置过程

1	0.000000	::	ff02::1:fffb:1894	ICMPv6	78 Neighbor Solicitation for fe80::2e0:fcff:fefb:1894
2	1.000000	fe80::2e0:fcff:fefb…	ff02::1	ICMPv6	78 Router Advertisement from 00:e0:fc:fb:18:94
3	1.985000	::	ff02::1:ff00:2	ICMPv6	78 Neighbor Solicitation for fc00:12::2

```
Ethernet II, Src: HuaweiTe_fb:18:94 (00:e0:fc:fb:18:94), Dst: IPv6mcast_01 (33:33:00:00:00:01)
> Destination: IPv6mcast_01 (33:33:00:00:00:01)
> Source: HuaweiTe_fb:18:94 (00:e0:fc:fb:18:94)
  Type: IPv6 (0x86dd)
Internet Protocol Version 6, Src: fe80::2e0:fcff:fefb:1894, Dst: ff02::1
  0110 .... = Version: 6
> .... 1100 0000 .... .... .... .... .... = Traffic Class: 0xc0 (DSCP: CS6, ECN: Not-ECT)
  .... .... .... 0000 0000 0000 0000 0000 = Flow Label: 0x00000
  Payload Length: 24
  Next Header: ICMPv6 (58)
  Hop Limit: 255
  Source: fe80::2e0:fcff:fefb:1894
  Destination: ff02::1
  [Source SA MAC: HuaweiTe_fb:18:94 (00:e0:fc:fb:18:94)]
Internet Control Message Protocol v6
  Type: Router Advertisement (134)
  Code: 0
  Checksum: 0x063f [correct]
  [Checksum Status: Good]
  Cur hop limit: 64
> Flags: 0x00, Prf (Default Router Preference): Medium
  Router lifetime (s): 1800
  Reachable time (ms): 0
  Retrans timer (ms): 0
> ICMPv6 Option (Source link-layer address : 00:e0:fc:fb:18:94)
```

R1 上配置其 GE0/0/0 接口

```
[R1]ivp
[R1]pv
[R1]ipv
[R1]ipv6
[R1]inter
[R1]interface Gig
[R1]interface GigabitEthernet 0/0/0
[R1-GigabitEthernet0/0/0]ipv
[R1-GigabitEthernet0/0/0]ipv6 en
[R1-GigabitEthernet0/0/0]ipv6 enable
[R1-GigabitEthernet0/0/0]inpv
[R1-GigabitEthernet0/0/0]ipv6 add
[R1-GigabitEthernet0/0/0]ipv6 address auto gl
[R1-GigabitEthernet0/0/0]ipv6 address auto global defa
[R1-GigabitEthernet0/0/0]ipv6 address auto global default
[R1-GigabitEthernet0/0/0]
Oct 14 2024 22:31:23-08:00 R1 IPV6/2/IF_IPV6CHANGE:OID 16777216.50331648.1006632
96.16777216.33554432.16777216.922746880.33554432.0.16777216 The status of the IP
v6 Interface changed. (IfIndex=50331648, IfDescr=HUAWEI, AR Series, GigabitEther
net0/0/0 Interface, IfOperStatus=16777216, IfAdminStatus=16777216)
[R1-GigabitEthernet0/0/0]
Oct 14 2024 22:31:23-08:00 R1 %%01IFNET/4/LINK_STATE(l)[0]:The line protocol IPv
6 on the interface GigabitEthernet0/0/0 has entered the UP state.
[R1-GigabitEthernet0/0/0]return
<R1>disp
<R1>display ipv
<R1>display ipv6 inter
<R1>display ipv6 interface bri
<R1>display ipv6 interface brief
*down: administratively down
(l): loopback
(s): spoofing
Interface                   Physical             Protocol
GigabitEthernet0/0/0        up                   up
[IPv6 Address] FC00:12::2E0:FCFF:FEA0:61E8
```

3. 观察 DAD 过程

在 R3 上配置静态 IPv6 地址

```
[R3]ipv
[R3]ipv6
[R3]inter
[R3]interface Gi
[R3]interface GigabitEthernet 0/0/0
[R3-GigabitEthernet0/0/0]ipv
[R3-GigabitEthernet0/0/0]ipv6 en
[R3-GigabitEthernet0/0/0]ipv6 enable
[R3-GigabitEthernet0/0/0]ipv
[R3-GigabitEthernet0/0/0]ipv6 addr
[R3-GigabitEthernet0/0/0]ipv6 address fc00:23::3 64
```

在 R2 上完成如下配置

```
[R2]interface GigabitEthernet 0/0/1
[R2-GigabitEthernet0/0/1]ipv
[R2-GigabitEthernet0/0/1]ipv6 en
[R2-GigabitEthernet0/0/1]ipv6 enable
[R2-GigabitEthernet0/0/1]ipv
[R2-GigabitEthernet0/0/1]ipv6 addr
                                 ^
Error:Incomplete command found at '^' position.
[R2-GigabitEthernet0/0/1]ipv6 add
[R2-GigabitEthernet0/0/1]ipv6 address fc00:23::3 64
```

捕获到如下报文

```
32.515000    fe80::2e0:fcff:fea0… fe80::2e0:fcff:fefb… ICMPv6    86 Neighbor Advertisement fe80::2e0:fcff:fea0:61e8 (rtr, sol, ovr) is at 00:e0:fc:a0:61:e8
Internet Control Message Protocol v6
   Type: Neighbor Advertisement (136)
   Code: 0
   Checksum: 0x6274 [correct]
   [Checksum Status: Good]
 > Flags: 0xe0000000, Router, Solicited, Override
   Target Address: fe80::2e0:fcff:fea0:61e8
 v ICMPv6 Option (Target link-layer address : 00:e0:fc:a0:61:e8)
     Type: Target link-layer address (2)
     Length: 1 (8 bytes)
     Link-layer address: HuaweiTe_a0:61:e8 (00:e0:fc:a0:61:e8)
```

4. 观察地址解析过程

将 R2 的接口地址修改为正确的地址

```
[R2]interface GigabitEthernet 0/0/1
[R2-GigabitEthernet0/0/1]undo ipv6 add
[R2-GigabitEthernet0/0/1]undo ipv6 address FC00:23::3/64
[R2-GigabitEthernet0/0/1]
Oct 14 2024 22:40:56-08:00 R2 IPV6/2/IF_IPV6CHANGE:OID 167
96.16777216.33554432.16777216.922746880.33554432.0.1677721
v6 Interface changed. (IfIndex=67108864, IfDescr=HUAWEI, A
net0/0/1 Interface, IfOperStatus=33554432, IfAdminStatus=1
[R2-GigabitEthernet0/0/1]
Oct 14 2024 22:40:56-08:00 R2 %%01IFNET/4/LINK_STATE(l)[1]
6 on the interface GigabitEthernet0/0/1 has entered the DO
[R2-GigabitEthernet0/0/1]ipv
[R2-GigabitEthernet0/0/1]ipv6 addr
[R2-GigabitEthernet0/0/1]ipv6 address fc00:23::2 64
```

在 R2 上 ping FC00:23::3

```
<R2>ping ipv6 FC00:23::3
  PING FC00:23::3 : 56  data bytes, press CTRL_C to break
    Reply from FC00:23::3
    bytes=56 Sequence=1 hop limit=64  time = 60 ms
    Reply from FC00:23::3
    bytes=56 Sequence=2 hop limit=64  time = 20 ms
    Reply from FC00:23::3
    bytes=56 Sequence=3 hop limit=64  time = 20 ms
    Reply from FC00:23::3
    bytes=56 Sequence=4 hop limit=64  time = 20 ms
    Reply from FC00:23::3
    bytes=56 Sequence=5 hop limit=64  time = 20 ms

  --- FC00:23::3 ping statistics ---
    5 packet(s) transmitted
    5 packet(s) received
    0.00% packet loss
    round-trip min/avg/max = 20/28/60 ms
```

11	5.031000	fe80::2e0:fcff:fefb:1895	fc00:23::3	ICMPv6	86	Neighbor Solicitation for fc00:23::3 from 00:e0:fc:fb:18:95
12	5.047000	fc00:23::3	fe80::2e0:fcff:fefb:1895	ICMPv6	86	Neighbor Advertisement fc00:23::3 (rtr, sol, ovr) is at 00:e0:f
13	5.172000	fe80::2e0:fcff:fedf:5d9d	fc00:23::2	ICMPv6	86	Neighbor Solicitation for fc00:23::2 from 00:e0:fc:df:5d:9d
14	5.187000	fc00:23::2	fe80::2e0:fcff:fedf:5d9d	ICMPv6	86	Neighbor Advertisement fc00:23::2 (rtr, sol, ovr) is at 00:e0:f
15	10.187000	fe80::2e0:fcff:fedf:5d9d	fe80::2e0:fcff:fefb:1895	ICMPv6	86	Neighbor Solicitation for fe80::2e0:fcff:fefb:1895 from 00:e0:f
16	10.187000	fe80::2e0:fcff:fefb:1895	fe80::2e0:fcff:fedf:5d9d	ICMPv6	86	Neighbor Advertisement fe80::2e0:fcff:fefb:1895 (rtr, sol, ovr)
17	11.047000	fe80::2e0:fcff:fefb:1895	fe80::2e0:fcff:fedf:5d9d	ICMPv6	86	Neighbor Solicitation for fe80::2e0:fcff:fedf:5d9d from 00:e0:f
18	11.047000	fe80::2e0:fcff:fedf:5d9d	fe80::2e0:fcff:fefb:1895	ICMPv6	86	Neighbor Advertisement fe80::2e0:fcff:fedf:5d9d (rtr, sol, ovr)

```
me 11: 86 bytes on wire (688 bits), 86 bytes captured (688 bits) on interface 0
ernet II, Src: HuaweiTe_fb:18:95 (00:e0:fc:fb:18:95), Dst: HuaweiTe_df:5d:9d (00:e0:fc:df:5d:9d)
ernet Protocol Version 6, Src: fe80::2e0:fcff:fefb:1895, Dst: fc00:23::3
ernet Control Message Protocol v6
Type: Neighbor Solicitation (135)
Code: 0
Checksum: 0x52f3 [correct]
[Checksum Status: Good]
Reserved: 00000000
Target Address: fc00:23::3
ICMPv6 Option (Source link-layer address : 00:e0:fc:fb:18:95)
```

12	5.047000	fc00:23::3	fe80::2e0:fcff:fefb:1895	ICMPv6	86 Neighbor Advertisement fc00:23::3 (rtr, sol, ovr) is at 00:e0:
13	5.172000	fe80::2e0:fcff:fedf:5d9d	fc00:23::2	ICMPv6	86 Neighbor Solicitation for fc00:23::2 from 00:e0:fc:df:5d:9d
14	5.187000	fc00:23::2	fe80::2e0:fcff:fedf:5d9d	ICMPv6	86 Neighbor Advertisement fc00:23::2 (rtr, sol, ovr) is at 00:e0:
15	10.187000	fe80::2e0:fcff:fedf:5d9d	fe80::2e0:fcff:fefb:1895	ICMPv6	86 Neighbor Solicitation for fe80::2e0:fcff:fefb:1895 from 00:e0:
16	10.187000	fe80::2e0:fcff:fefb:1895	fe80::2e0:fcff:fedf:5d9d	ICMPv6	86 Neighbor Advertisement fe80::2e0:fcff:fefb:1895 (rtr, sol, ovr
17	11.047000	fe80::2e0:fcff:fefb:1895	fe80::2e0:fcff:fedf:5d9d	ICMPv6	86 Neighbor Solicitation for fe80::2e0:fcff:fedf:5d9d from 00:e0:
18	11.047000	fe80::2e0:fcff:fedf:5d9d	fe80::2e0:fcff:fefb:1895	ICMPv6	86 Neighbor Advertisement fe80::2e0:fcff:fedf:5d9d (rtr, sol, ovr

```
rame 12: 86 bytes on wire (688 bits), 86 bytes captured (688 bits) on interface 0
thernet II, Src: HuaweiTe_df:5d:9d (00:e0:fc:df:5d:9d), Dst: HuaweiTe_fb:18:95 (00:e0:fc:fb:18:95)
nternet Protocol Version 6, Src: fc00:23::3, Dst: fe80::2e0:fcff:fefb:1895
nternet Control Message Protocol v6
 Type: Neighbor Advertisement (136)
 Code: 0
 Checksum: 0x2c06 [correct]
 [Checksum Status: Good]
 Flags: 0xe0000000, Router, Solicited, Override
 Target Address: fc00:23::3
 ICMPv6 Option (Target link-layer address : 00:e0:fc:df:5d:9d)
```

5. 捕获 Ping 报文

	Time	Source	Destination	Protoco	Length	Info
1	0.000000	fc00:23::2	fc00:23::3	ICMPv6	118	Echo (ping) request id=0xdcab, seq=256, hop limit=64 (reply in
2	0.000000	fc00:23::3	fc00:23::2	ICMPv6	118	Echo (ping) reply id=0xdcab, seq=256, hop limit=64 (request in
3	0.484000	fc00:23::2	fc00:23::3	ICMPv6	118	Echo (ping) request id=0xdcab, seq=512, hop limit=64 (reply in
4	0.500000	fc00:23::3	fc00:23::2	ICMPv6	118	Echo (ping) reply id=0xdcab, seq=512, hop limit=64 (request in
5	0.984000	fc00:23::2	fc00:23::3	ICMPv6	118	Echo (ping) request id=0xdcab, seq=768, hop limit=64 (reply in
6	1.000000	fc00:23::3	fc00:23::2	ICMPv6	118	Echo (ping) reply id=0xdcab, seq=768, hop limit=64 (request in
7	1.484000	fc00:23::2	fc00:23::3	ICMPv6	118	Echo (ping) request id=0xdcab, seq=1024, hop limit=64 (reply in
8	1.484000	fc00:23::3	fc00:23::2	ICMPv6	118	Echo (ping) reply id=0xdcab, seq=1024, hop limit=64 (request in
9	1.984000	fc00:23::2	fc00:23::3	ICMPv6	118	Echo (ping) request id=0xdcab, seq=1280, hop limit=64 (reply in
10	1.984000	fc00:23::3	fc00:23::2	ICMPv6	118	Echo (ping) reply id=0xdcab, seq=1280, hop limit=64 (request in
11	5.031000	fe80::2e0:fcff:fefb:1895	fc00:23::3	ICMPv6	86	Neighbor Solicitation for fc00:23::3 from 00:e0:fc:fb:18:95
12	5.047000	fc00:23::3	fe80::2e0:fcff:fefb:1895	ICMPv6	86	Neighbor Advertisement fc00:23::3 (rtr, sol, ovr) is at 00:e0:
13	5.172000	fe80::2e0:fcff:fedf:5d9d	fc00:23::2	ICMPv6	86	Neighbor Solicitation for fc00:23::2 from 00:e0:fc:df:5d:9d
14	5.187000	fc00:23::2	fe80::2e0:fcff:fedf:5d9d	ICMPv6	86	Neighbor Advertisement fc00:23::2 (rtr, sol, ovr) is at 00:e0:
15	10.187000	fe80::2e0:fcff:fedf:5d9d	fe80::2e0:fcff:fefb:1895	ICMPv6	86	Neighbor Solicitation for fe80::2e0:fcff:fefb:1895 from 00:e0:
16	10.187000	fe80::2e0:fcff:fefb:1895	fe80::2e0:fcff:fedf:5d9d	ICMPv6	86	Neighbor Advertisement fe80::2e0:fcff:fefb:1895 (rtr, sol, ovr
17	11.047000	fe80::2e0:fcff:fefb:1895	fe80::2e0:fcff:fedf:5d9d	ICMPv6	86	Neighbor Solicitation for fe80::2e0:fcff:fedf:5d9d from 00:e0:
18	11.047000	fe80::2e0:fcff:fedf:5d9d	fe80::2e0:fcff:fefb:1895	ICMPv6	86	Neighbor Advertisement fe80::2e0:fcff:fedf:5d9d (rtr, sol, ovr

```
Frame 1: 118 bytes on wire (944 bits), 118 bytes captured (944 bits) on interface 0
Ethernet II, Src: HuaweiTe_fb:18:95 (00:e0:fc:fb:18:95), Dst: HuaweiTe_df:5d:9d (00:e0:fc:df:5d:9d)
Internet Protocol Version 6, Src: fc00:23::2, Dst: fc00:23::3
Internet Control Message Protocol v6
   Type: Echo (ping) request (128)
   Code: 0
   Checksum: 0x19bd [correct]
   [Checksum Status: Good]
   Identifier: 0xdcab
   Sequence: 256
   [Response In: 2]
 > Data (56 bytes)
```

6. 捕获 Tracert 报文

在 R3 上添加默认路由

```
[R3]ipv6 route-static :: 0 fc00:23::2
```

在 R1 上执行如下命令

```
<R1>tracert ipv6 fc00:23::3

 traceroute to fc00:23::3  30 hops max,60 bytes packet

 1 FC00:12::2 60 ms  20 ms  20 ms

 2 FC00:23::3 20 ms  20 ms  20 ms
```

19	293.031000	fc00:12::2e0:fcff:fea0:6…	fc00:23::3	UDP	74 30037 → 33437 Len=12
20	293.031000	fc00:23::3	fc00:12::2e0:fcff:fea0:6…	ICMPv6	122 Destination Unreachable (Port unreachable)
21	293.047000	fc00:12::2e0:fcff:fea0:6…	fc00:23::3	UDP	74 30037 → 33438 Len=12
22	293.047000	fc00:23::3	fc00:12::2e0:fcff:fea0:6…	ICMPv6	122 Destination Unreachable (Port unreachable)
23	293.062000	fc00:12::2e0:fcff:fea0:6…	fc00:23::3	UDP	74 30037 → 33439 Len=12
24	293.078000	fc00:23::3	fc00:12::2e0:fcff:fea0:6…	ICMPv6	122 Destination Unreachable (Port unreachable)
25	298.281000	fe80::2e0:fcff:fedf:5d9d	fc00:23::2	ICMPv6	86 Neighbor Solicitation for fc00:23::2 from 00:e0:fc:df:5d:9d
26	298.281000	fc00:23::2	fe80::2e0:fcff:fedf:5d9d	ICMPv6	86 Neighbor Advertisement fc00:23::2 (rtr, sol, ovr) is at 00:e0…
27	304.172000	fe80::2e0:fcff:fefb:1895	fe80::2e0:fcff:fedf:5d9d	ICMPv6	86 Neighbor Solicitation for fe80::2e0:fcff:fedf:5d9d from 00:e0…
28	304.172000	fe80::2e0:fcff:fedf:5d9d	fe80::2e0:fcff:fefb:1895	ICMPv6	86 Neighbor Advertisement fe80::2e0:fcff:fedf:5d9d (rtr, sol, ov…
29	309.265000	fe80::2e0:fcff:fedf:5d9d	fe80::2e0:fcff:fefb:1895	ICMPv6	86 Neighbor Solicitation for fe80::2e0:fcff:fefb:1895 from 00:e0…
30	309.281000	fe80::2e0:fcff:fefb:1895	fe80::2e0:fcff:fedf:5d9d	ICMPv6	86 Neighbor Advertisement fe80::2e0:fcff:fefb:1895 (rtr, sol, ov…

7. 观察 IPv6 PMTUD 机制

```
[R2]interface GigabitEthernet 0/0/1
[R2-GigabitEthernet0/0/1]ipv
[R2-GigabitEthernet0/0/1]ipv6 mtu 1280
[R2-GigabitEthernet0/0/1]quit
```

```
<R1>ping ipv6 -s 1233 fc00:23::3
  PING fc00:23::3 : 1233  data bytes, press CTRL_C to break
    Request time out
    Reply from FC00:23::3
    bytes=1233 Sequence=2 hop limit=63  time = 30 ms
    Reply from FC00:23::3
    bytes=1233 Sequence=3 hop limit=63  time = 20 ms
    Reply from FC00:23::3
    bytes=1233 Sequence=4 hop limit=63  time = 40 ms
    Reply from FC00:23::3
    bytes=1233 Sequence=5 hop limit=63  time = 30 ms

  --- fc00:23::3 ping statistics ---
    5 packet(s) transmitted
    4 packet(s) received
    20.00% packet loss
    round-trip min/avg/max = 20/30/40 ms
```

21	120.937000	fc00:12::2e0:fcff:fea0:6…	fc00:23::3	IPv6	1294 IPv6 fragment (off=0 more=y ident=0x0000000a nxt=58)
22	120.937000	fc00:12::2e0:fcff:fea0:6…	fc00:23::3	ICMPv6	71 Echo (ping) request id=0xd2ab, seq=256, hop limit=64 (reply i…
23	120.953000	fc00:23::3	fc00:12::2e0:fcff:fea0:6…	ICMPv6	1295 Echo (ping) reply id=0xd2ab, seq=256, hop limit=63 (request i…
24	121.437000	fc00:12::2e0:fcff:fea0:6…	fc00:23::3	IPv6	1294 IPv6 fragment (off=0 more=y ident=0x0000000b nxt=58)
25	121.437000	fc00:12::2e0:fcff:fea0:6…	fc00:23::3	ICMPv6	71 Echo (ping) request id=0xd2ab, seq=512, hop limit=64 (reply i…
26	121.453000	fc00:23::3	fc00:12::2e0:fcff:fea0:6…	ICMPv6	1295 Echo (ping) reply id=0xd2ab, seq=512, hop limit=63 (request i…
27	121.937000	fc00:12::2e0:fcff:fea0:6…	fc00:23::3	IPv6	1294 IPv6 fragment (off=0 more=y ident=0x0000000c nxt=58)
28	121.937000	fc00:12::2e0:fcff:fea0:6…	fc00:23::3	ICMPv6	71 Echo (ping) request id=0xd2ab, seq=768, hop limit=64 (reply i…
29	121.953000	fc00:23::3	fc00:12::2e0:fcff:fea0:6…	ICMPv6	1295 Echo (ping) reply id=0xd2ab, seq=768, hop limit=63 (request i…
30	122.437000	fc00:12::2e0:fcff:fea0:6…	fc00:23::3	IPv6	1294 IPv6 fragment (off=0 more=y ident=0x0000000d nxt=58)
31	122.437000	fc00:12::2e0:fcff:fea0:6…	fc00:23::3	ICMPv6	71 Echo (ping) request id=0xd2ab, seq=1024, hop limit=64 (reply …
32	122.453000	fc00:23::3	fc00:12::2e0:fcff:fea0:6…	ICMPv6	1295 Echo (ping) reply id=0xd2ab, seq=1024, hop limit=63 (request …
33	122.937000	fc00:12::2e0:fcff:fea0:6…	fc00:23::3	IPv6	1294 IPv6 fragment (off=0 more=y ident=0x0000000e nxt=58)
34	122.937000	fc00:12::2e0:fcff:fea0:6…	fc00:23::3	ICMPv6	71 Echo (ping) request id=0xd2ab, seq=1280, hop limit=64 (reply …
35	122.953000	fc00:23::3	fc00:12::2e0:fcff:fea0:6…	ICMPv6	1295 Echo (ping) reply id=0xd2ab, seq=1280, hop limit=63 (request …
36	126.484000	fe80::2e0:fcff:fea0:61e8	fe80::2e0:fcff:fefb:1894	ICMPv6	86 Neighbor Solicitation for fe80::2e0:fcff:fefb:1894 from 00:e0…
37	126.484000	fe80::2e0:fcff:fefb:1894	fe80::2e0:fcff:fea0:61e8	ICMPv6	86 Neighbor Advertisement fe80::2e0:fcff:fefb:1894 (rtr, sol, ov…
38	131.953000	fe80::2e0:fcff:fefb:1894	fe80::2e0:fcff:fea0:61e8	ICMPv6	86 Neighbor Solicitation for fe80::2e0:fcff:fea0:61e8 from 00:e0…
39	131.953000	fe80::2e0:fcff:fea0:61e8	fe80::2e0:fcff:fefb:1894	ICMPv6	86 Neighbor Advertisement fe80::2e0:fcff:fea0:61e8 (rtr, sol, ov…

```
ıe 21: 1294 bytes on wire (10352 bits), 1294 bytes captured (10352 bits) on interface 0
ɛrnet II, Src: HuaweiTe_a0:61:e8 (00:e0:fc:a0:61:e8), Dst: HuaweiTe_fb:18:94 (00:e0:fc:fb:18:94)
ɛrnet Protocol Version 6, Src: fc00:12::2e0:fcff:fea0:61e8, Dst: fc00:23::3
ı (1232 bytes)
```

```
<R1>display ipv6 pathmtu all
IPv6 Destination Address                ZoneID PathMTU LifeTime(M) Type    FF
FC00:23::3                              0      1280    6           Dynamic No
--------------------------------------------------------------------------------

Total: 1       Dynamic: 1      Static: 0
```

4 实验代码

本次实验的代码已上传于以下代码仓库：CNI-Exp: 厦门大学计算机网络课程实验项目集 (gitee.com)

5 课后思考题

7.1

1. IPv6 无状态地址自动配置与 DHCPv6 地址自动配置的区别是？

对于前者，IPv6 地址通过路由告知 RA 方式生成，其他参数通过 DHCPv6 获取；对于后者，IPv6 地址、其他参数均通过 DHCPv6 获取

2. 在本实验中，我们使用路由器作为 IPv6 无状态地址自动配置的客户端，它依据什么规范生成的 IPv6 接口 ID 并在获取 IPv6 地址前缀后最终形成单播地址？这个规范具体的操作过程是什么？

通过 IEEE EUI-64 规范。

过程：

原 U/L 位如果是 0（表示全局唯一），则转换为 1；如果是 1（表示本地管理），则转换为 0。

在翻转后的 MAC 地址 OUI 字段和 EUI 字段之间插入十六进制数 FFFE，使原来的 48 位 MAC 地址扩展到 64 位。

将从 48 位 MAC 地址扩展得到的 64 位字段与网络前缀结合形成完整的 128 位 IPv6 单播地址。

7.2

1. 当我们在路由器的 IPv6 接口上执行 undo ipv6 nd ra halt 命令后，该接口将周期性地发送 RA 报文，这些报文的目的 IPv6 地址是？该报文的载荷有什么内容？

RA 发送到所有节点的链路本地多播地址 FF02::1 或路由器请求节点的单播地址。

内容包含是否使用自动配置、一个或多个本地链路前缀、生存期、缺省路由、跳数限制、最大 MTU 等。

2. 当一台设备的接口获得 IPv6 地址后，设备立即启动 DAD 过程并在接口上发送一个 NS 报文用于检测该地址是否已被使用，这个 NS 报文的目的 IPv6 地址是什么？这个地址是如何形成的？

目的地址是需要解析的 IPv6 地址对应的被请求节点组播地址

如何形成：

首先确定被请求节点的地址格式为：FF02::1：FF00/104，将地址被请求者的单播 IP 地址的后 24 位填补在被请求节点地址的背后形成 NS 报文的目的 IP 地址，将 3333+被请求节点地址的后 32 位形成 NS 报文的目的 mac 地址

3. IPv6 报文头部中的“Hop Limit”字段有什么用途

指定了报文可以有效转发的次数，类似于 TTL，为 0 是被丢弃

6 实验总结

本次实验实践了静态 IPv6 地址配置、IPv6 地址无状态自动配置、DHCPv6 地址自动配置三种 IPv6 地址配置方式，在此基础上进行了连通性测试、抓包进行报文分析、DAD 机制的检验、PMTUD 机制的检验，对 IPv6 网络中的报文捕获与分析有了更深入的理解