

## NAT 网络地址转换

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### 【实验目的】

- 1.通过实验理解、体会地址转换原理（NAT），理解私有网络与互联网互通原理。
- 2.了解 NAT 技术并能进行相关的配置操作。
- 3.理解与掌握网络地址转换技术，并理解其对于网络安全的意义。

### 【实验原理】

#### 1.网络地址转换技术

网络地址转换技术（Network Address Translation,NAT），是指在实施包过滤机制时，通过对 IP 数据包地址进行改变从而实现不同地址类型转换的一种技术。网络地址转换技术用途广泛，可用于私有网络与互联网互通，家庭接入互联网共享等网络应用。其能够解决 IP 地址不足的问题（32 位的 IP 地址并不是太多），同时还能有效保护来自网络外部的攻击，隐藏并保护网络内部的计算机。

#### 2.网络地址转换原理

私有网络开展网络应用，也需要使用 IP 地址，但是是一种私有地址，如同济大学以 10 开头的私有网络地址，通常情况下私有网络地址不能够和互联网进行连通，因为互联网路由器不支持私有地址，其路由表不允许设置私有地址条目，通信时，IP 数据包能够外出到达互联网，但无法返回源节点，而通过实施网络地址转换可以实现私有网络与互联网互通。

其原理为利用连接双方的路由器，在实施包过滤机制时进行地址转换，当从私有网络前往互联网时，就将私有地址转换成一个标准 IP 地址（并在 NAT 转换表中保存这条记录），当从互联网返回私有网络时，就将这个标准 IP 地址再转换回私有地址（通过查看当前 NAT 转换表），如此实现私有网络和互联网互联，私有网络和互联网通常称为内网和外网。

### 3.网络地址转换技术特点

NAT 技术将外网地址作为工作地址，内网内可以直接使用该工作地址，而外网却不能够直接访问内网地址，必须使用其转换地址，而转换地址需要一定途径才能获得。因此 NAT 技术能够很好解决私有网络和外网的互联问题，让私有网络实现信息服务共享，同时还具备一定的安全作用，可以有效控制对外网对私有网络的主机地址进行访问，允许转换的网络接受外部访问，不允许转换的地址则拒绝访问。

### 4.网络地址转换技术分类

NAT 将网络划分为内网、外网两部分，内网节点利用 NAT 访问外网时，NAT 将内网地址替换为合法的 IP 标准地址，然后将数据包转发，在数据包从外网返回内网时，NAT 将外网地址替换为内网地址然后转发给相应节点，整个过程通过维护一个 NAT 转换表实现。

网络地址转换分为两种类型：NAT（如上述介绍），NAPT（网络地址端口转换 Network Address Port Translation，将端口地址也加入作为转换内容，能够实现多个私网节点同时共享一个互联网地址，家庭共享上网采用这种方式）。

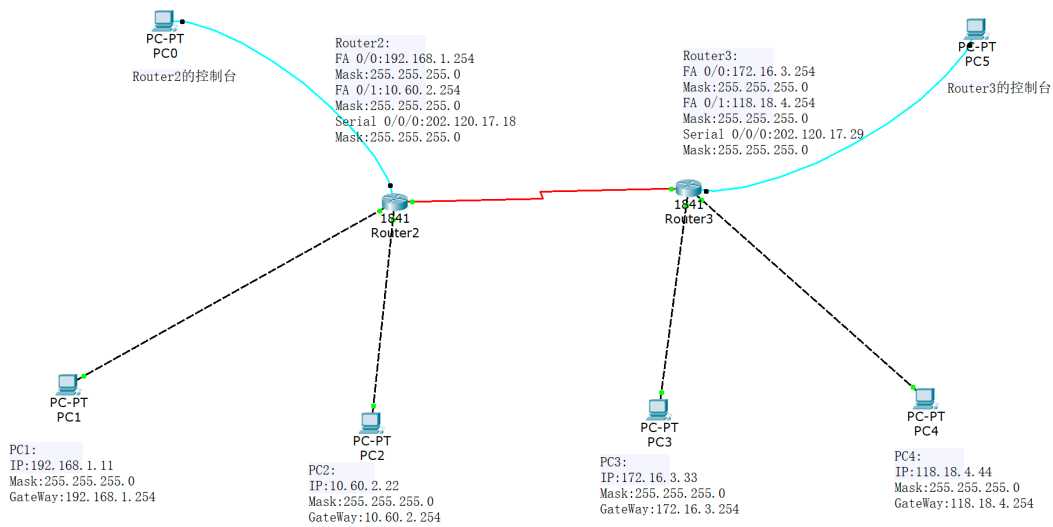
NAT 又可分为静态 NAT 和动态 NAT，静态 NAT 是实现内网地址和外网地址一对一映射，而动态 NAT 是一个地址池，实现内网地址和外网地址一对多映射，应用较少。

### 【实验设备】

- 1.一台运行 Windows 的计算机。
- 2.Cisco 仿真终端软件 Cisco Packet Tracer。

### 【实验步骤】

- 1.首先规划网络结构及其拓扑。
- 2.根据网络拓扑图（如下）配置响应 PC、路由器端口、串口的 IP 地址、子网掩码等信息。



路由器相关配置命令如下：

Router2:

```
interface FastEthernet 0/0
ip address 192.168.1.254 255.255.255.0
interface FastEthernet 0/1
ip address 10.60.2.254 255.255.255.0
no shutdown
```

```
interface Serial 0/0/0
ip address 202.120.17.18 255.255.255.0
Clock rate 56000
no shutdown
```

Router3:

```
interface FastEthernet 0/0
ip address 172.16.3.254 255.255.255.0
interface FastEthernet 0/1
ip address 118.8.4.254 255.255.255.0
no shutdown
```

```
interface Serial 0/0/0
ip address 202.120.17.29 255.255.255.0
Clock rate 56000
no shutdown
```

3.在各路由器上配置静态路由协议，让 PC 间能够相互连通（Ping）。

静态路由表配置命令如下：

Router2:

```
ip route 218.100.3.0 255.255.255.0 serial 0/0/0
ip route 118.18.4.0 255.255.255.0 serial 0/0/0
```

Router3:

```
ip route 10.60.2.0 255.255.255.0 serial 0/0/0
ip route 210.120.1.0 255.255.255.0 serial 0/0/0
```

4.在路由器上配置静态 NAT。

NAT 相关配置命令如下：

Router2:

```
interface FastEthernet 0/0
ip nat inside //配置以太网端口实施入口 NAT 转换
interface Serial 0/0/0
ip nat outside //配置串口实施出口 NAT 转换
```

Router3:

```
interface FastEthernet 0/0
ip nat inside //配置以太网端口实施入口 NAT 转换
interface Serial 0/0/0
ip nat outside //配置串口实施出口 NAT 转换
```

5.在路由器上定义内、外部网络接口。

配置路由器 NAT 转换相关命令如下：

router2:

```
ip nat inside source static 192.168.1.11 210.120.1.11
```

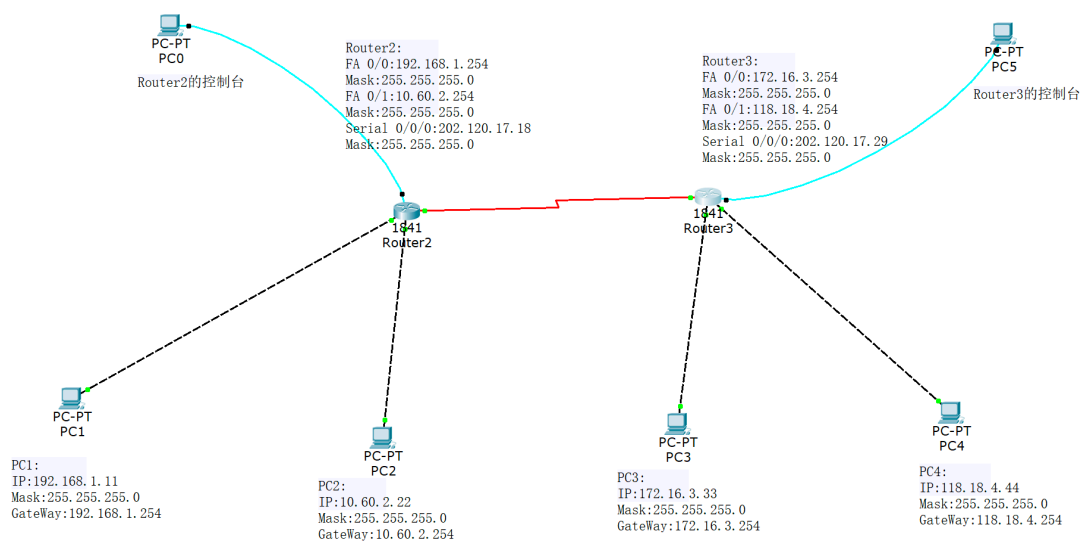
router3:

```
ip nat inside source static 172.16.3.33 218.100.3.33
```

6.再次验证各主机之间的连通性，检测从内网访问外网连通性如何，从外网访问内网连通性如何。

### 【实验现象】

1.网络拓扑结构如下图。



2.PC、路由器端口、串口配置信息如下。

PC 的 IP 地址、子网掩码、网关配置如下。

PC1

Physical Config Desktop Custom Interface

**GLOBAL**

Settings

Algorithm Settings

Firewall

IPv6 Firewall

**INTERFACE**

FastEthernet0

**FastEthernet0**

Port Status ☒ On

Bandwidth ☒ Auto

☐ 10 Mbps ☒ 100 Mbps

Duplex ☒ Auto

☒ Full Duplex ☐ Half Duplex

MAC Address 00D0.D34B.4939

IP Configuration

☐ DHCP

☒ Static

IP Address 192.168.1.11

Subnet Mask 255.255.255.0

IPv6 Configuration

Link Local Address: FE80::2D0:D3FF:FE4B:4939

☐ DHCP

☐ Auto Config

☒ Static

IPv6 Address /

路由器网卡 IP 地址、子网掩码如下。

Router2

Physical Config CLI

**ROUTING**

Static

RIP

**WITCHIN**

AN Database

**INTERFACE**

FastEthernet0/0

FastEthernet0/0

Serial0/0/0

Serial0/0/1

**FastEthernet0/0**

Port Status ☒ On

Bandwidth ☒ Auto

☐ 10 Mbps ☒ 100 Mbps

Duplex ☒ Auto

☒ Full Duplex ☐ Half Duplex

MAC Address 0001.C955.5201

IP Address 192.168.1.254

Subnet Mask 255.255.255.0

Tx Ring Limit 10

**Equivalent IOS Commands**

```
Router(config-router)#exit
Router(config)#ip route 172.16.3.0 255.255.255.0 serial 0/0/0
Router(config)#ip route 118.18.4.0 255.255.255.0 serial 0/0/0
Router(config)#
Router(config)#
Router(config)#interface FastEthernet0/0
Router(config-if)#
```

路由器串口 IP 地址、子网掩码配置如下。

Router2

Physical
Config
CLI

ROUTING
Static
RIP
WITCHIN
AN Databa
NTERFAC
stEthernetC
stEthernetC
Serial0/0/0
Serial0/0/1

Serial0/0/0

Port Status
Clock Rate
Duplex
IP Address
Subnet Mask
Tx Ring Limit

☒ On

56000

☒ Full Duplex

202.120.17.18

255.255.255.0

10

Equivalent IOS Commands

Router(config)#  
Router(config)#interface FastEthernet0/0  
Router(config-if)#  
Router(config-if)#exit  
Router(config)#interface Serial0/0/0  
Router(config-if)#  
Router(config-if)#exit  
Router(config)#interface FastEthernet0/0  
Router(config-if)#  
Router(config-if)#exit  
Router(config)#interface Serial0/0/0  
Router(config-if)#

3.在路由器上添加静态路由如下。

Router2

Physical
Config
CLI

GLOBAL
Settings
brithm Setti
ROUTING
Static
RIP
WITCHIN
AN Databa
NTERFAC
stEthernetC

Static Routes

Network
Mask
Next Hop

Add

Network Address

118.18.4.0/24 via Serial0/0/0  
218.100.3.0/24 via Serial0/0/0

Remove

Equivalent IOS Commands

Router(config)#  
Enter configuration commands, one per line. End with CNTL/Z.  
Router(config)#no ip route 172.16.3.0 255.255.255.0 Serial0/0/0  
Router(config)#ip ro  
Router(config)#ip route 218.100.3.0 255.255.255.0 seri  
Router(config)#ip route 218.100.3.0 255.255.255.0 serial 0/0/0  
Router(config)#  
Router(config)#

Router3

Physical

Config

CLI

GLOBAL

Settings

Algorithm Settings

ROUTING

Static

RIP

WITCHIN

AN Database

INTERFAC

stEthernet0

Static Routes

Network

Mask

Next Hop

10.60.2.0/24 via Serial0/0/0

210.120.1.0/24 via Serial0/0/0

Add

Remove

Equivalent IOS Commands

```

Router(config)#ip route 192.168.1.0 255.255.255.0 Serial0/0/0
Router(config)#ip ro
Router(config)#ip route 210.120.1.11 255.255.255.0 ser
Router(config)#ip route 210.120.1.11 255.255.255.0 serial 0/0/0
%Inconsistent address and mask
Router(config)#ip route 210.120.1.0 255.255.255.0 ser
Router(config)#ip route 210.120.1.0 255.255.255.0 serial 0/0/0
Router(config)#
Router(config)#

```

PC 之间 Ping 连通性测试。



## Command Prompt

```
Packet Tracer PC Command Line 1.0
PC>ping
PC>
PC>ping 10.60.2.22

Pinging 10.60.2.22 with 32 bytes of data:

Reply from 10.60.2.22: bytes=32 time=1ms TTL=127
Reply from 10.60.2.22: bytes=32 time=0ms TTL=127
Reply from 10.60.2.22: bytes=32 time=0ms TTL=127
Reply from 10.60.2.22: bytes=32 time=0ms TTL=127

Ping statistics for 10.60.2.22:
    Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),
    Approximate round trip times in milli-seconds:
        Minimum = 0ms, Maximum = 1ms, Average = 0ms

PC>ping 10.60.2.22

Pinging 10.60.2.22 with 32 bytes of data:

Reply from 10.60.2.22: bytes=32 time=1ms TTL=127
Reply from 10.60.2.22: bytes=32 time=0ms TTL=127
Reply from 10.60.2.22: bytes=32 time=0ms TTL=127
Reply from 10.60.2.22: bytes=32 time=0ms TTL=127

Ping statistics for 10.60.2.22:
    Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),
    Approximate round trip times in milli-seconds:
        Minimum = 0ms, Maximum = 1ms, Average = 0ms

PC>ping 172.16.3.33

Pinging 172.16.3.33 with 32 bytes of data:

Reply from 192.168.1.254: Destination host unreachable.
Reply from 192.168.1.254: Destination host unreachable.
Reply from 192.168.1.254: Destination host unreachable.
Request timed out.

Ping statistics for 172.16.3.33:
    Packets: Sent = 4, Received = 0, Lost = 4 (100% loss),

PC>ping 118.18.4.44

Pinging 118.18.4.44 with 32 bytes of data:

Request timed out.
Request timed out.
Request timed out.
Request timed out.

Ping statistics for 118.18.4.44:
    Packets: Sent = 4, Received = 0, Lost = 4 (100% loss),

PC>|
```

PC1 的 ping 解释：由于 IP 为 10.60.2.22 的主机与 PC1 共同连接于一个路由器，所以无需添加路由表路由器也能进行存储-转发，因此 PC1-PC2 连通；而 172.16.3.33 的主机在另一个子网中且且路由器路由表中没有关于目标地址为 172.16.3.33 的跳转条目，因此收到网关的回复是目标主机不能到达；IP 为 118.18.4.44 的主机由于在路由器路由表中有关于该目标地址的跳转条目，因此路由器能够进行正确的路径选择并将数据包递交到 118.18.4.44，但是在 118.18.4.44 的主机进行回复时，由于其路由器路由表中并没有目标地址为 192.168.1.11 的跳转条目，因此数据包无法返回 192.168.1.11，因此其中的反馈是请求超时，，即只是建立了单方面连接。

## Command Prompt

Packet Tracer PC Command Line 1.0

PC>ping 118.18.4.44

Pinging 118.18.4.44 with 32 bytes of data:

Reply from 118.18.4.44: bytes=32 time=2ms TTL=126  
Reply from 118.18.4.44: bytes=32 time=12ms TTL=126  
Reply from 118.18.4.44: bytes=32 time=18ms TTL=126  
Reply from 118.18.4.44: bytes=32 time=18ms TTL=126

Ping statistics for 118.18.4.44:

Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),  
Approximate round trip times in milli-seconds:  
Minimum = 2ms, Maximum = 18ms, Average = 12ms

PC>ping 172.16.3.33

Pinging 172.16.3.33 with 32 bytes of data:

Reply from 10.60.2.254: Destination host unreachable.  
Reply from 10.60.2.254: Destination host unreachable.  
Reply from 10.60.2.254: Destination host unreachable.  
Reply from 10.60.2.254: Destination host unreachable.

Ping statistics for 172.16.3.33:

Packets: Sent = 4, Received = 0, Lost = 4 (100% loss),

PC>ping 118.18.4.44

Pinging 118.18.4.44 with 32 bytes of data:

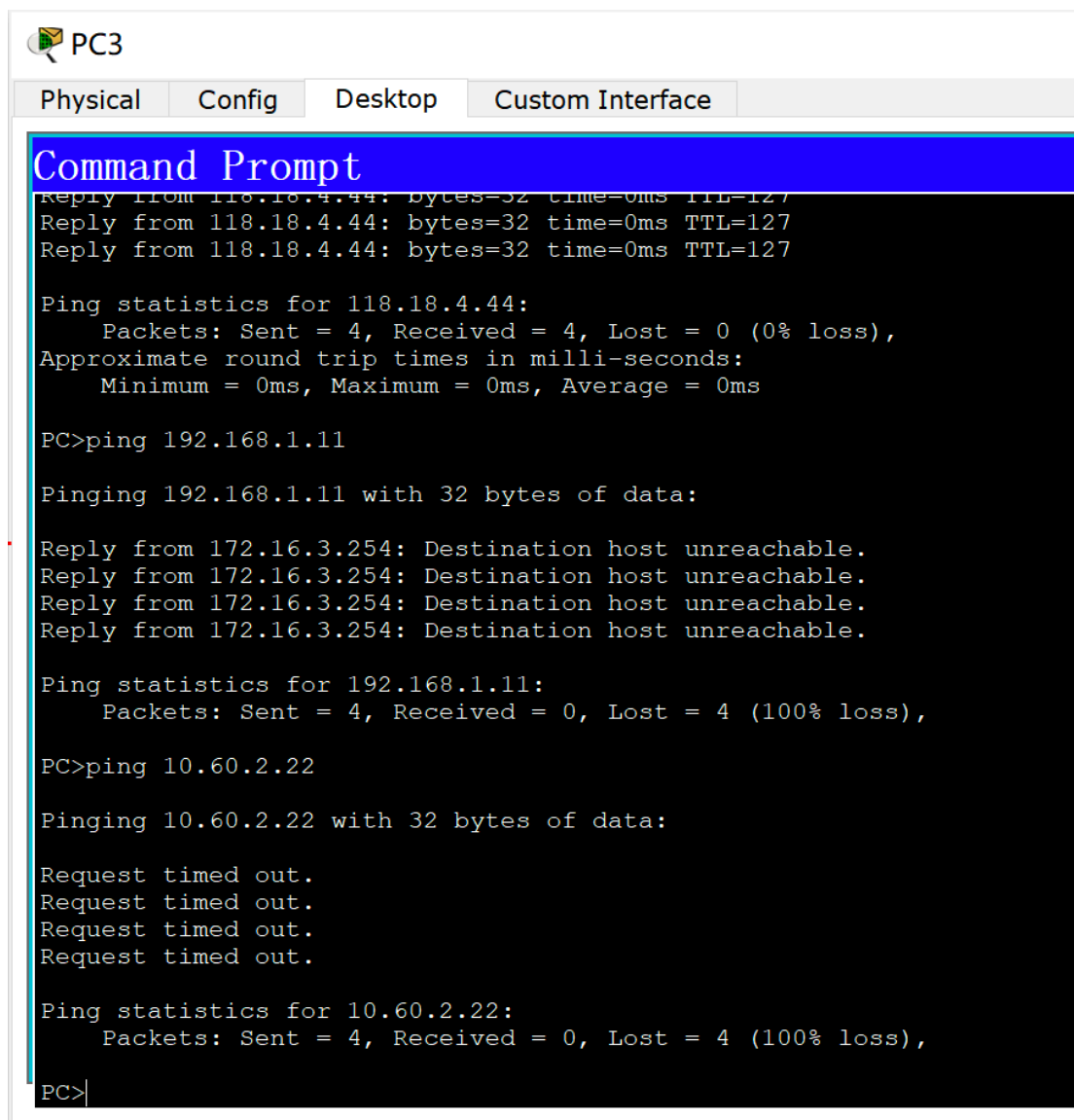
Reply from 118.18.4.44: bytes=32 time=20ms TTL=126  
Reply from 118.18.4.44: bytes=32 time=16ms TTL=126  
Reply from 118.18.4.44: bytes=32 time=2ms TTL=126  
Reply from 118.18.4.44: bytes=32 time=19ms TTL=126

Ping statistics for 118.18.4.44:

Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),  
Approximate round trip times in milli-seconds:  
Minimum = 2ms, Maximum = 20ms, Average = 14ms

PC>|

PC2 的 ping 解释：由于在其路由表总没有目标地址为 172.16.3.33 的跳转条目，因此反馈为目标主机不可到达；而在本地路由由于具有目标地址为 118.18.4.44 的跳转条目，且在数据包回复时路由表中也有目标地址为 10.60.2.22 的跳转条目。因此本次的数据包发送接受成功，即 PC2-PC4 连通成功。



PC3

Physical Config Desktop Custom Interface

### Command Prompt

```
Reply from 118.18.4.44: bytes=32 time=0ms TTL=127
Reply from 118.18.4.44: bytes=32 time=0ms TTL=127
Reply from 118.18.4.44: bytes=32 time=0ms TTL=127

Ping statistics for 118.18.4.44:
    Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),
    Approximate round trip times in milli-seconds:
        Minimum = 0ms, Maximum = 0ms, Average = 0ms

PC>ping 192.168.1.11

Pinging 192.168.1.11 with 32 bytes of data:

Reply from 172.16.3.254: Destination host unreachable.
Reply from 172.16.3.254: Destination host unreachable.
Reply from 172.16.3.254: Destination host unreachable.
Reply from 172.16.3.254: Destination host unreachable.

Ping statistics for 192.168.1.11:
    Packets: Sent = 4, Received = 0, Lost = 4 (100% loss),

PC>ping 10.60.2.22

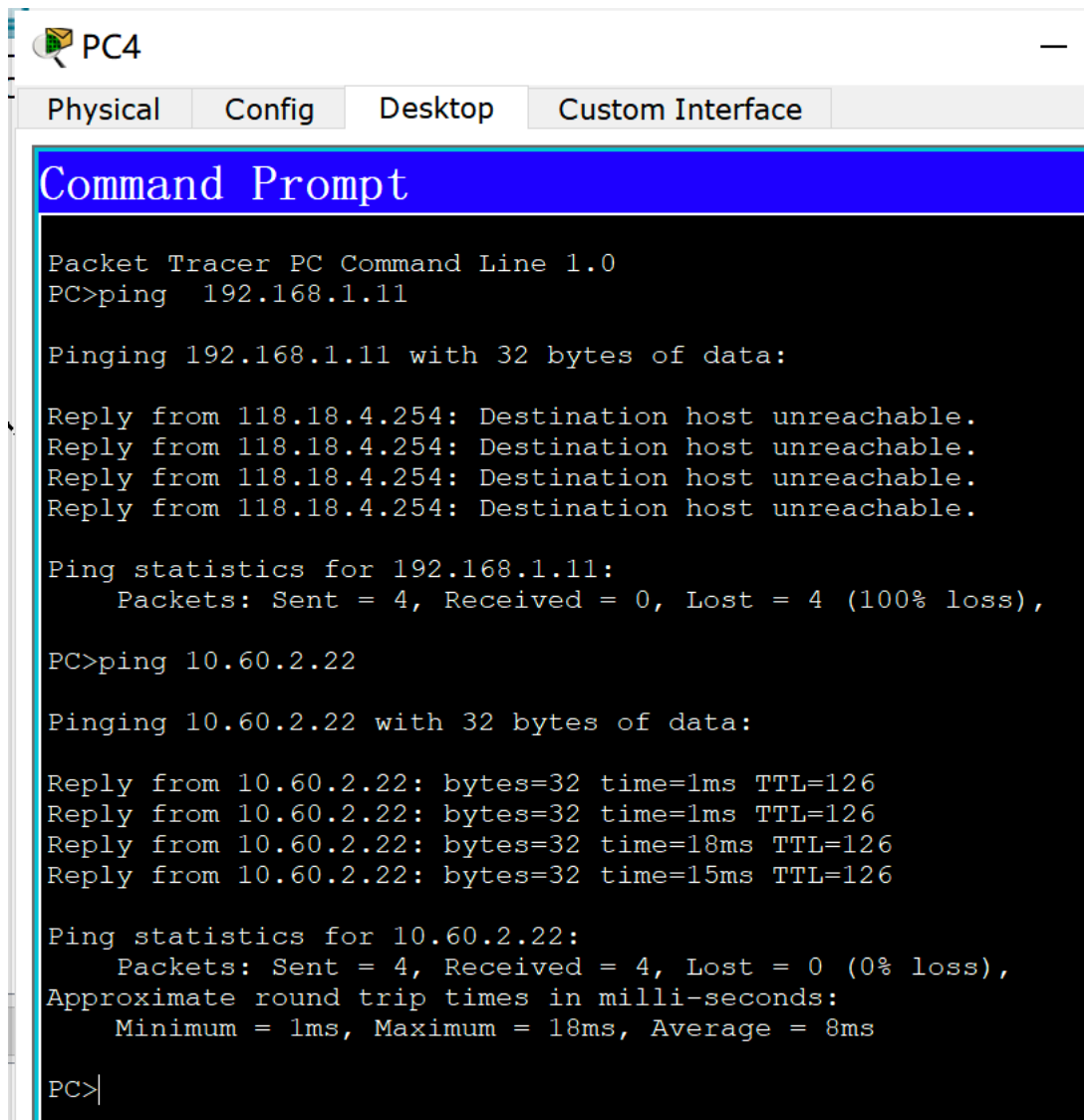
Pinging 10.60.2.22 with 32 bytes of data:

Request timed out.
Request timed out.
Request timed out.
Request timed out.

Ping statistics for 10.60.2.22:
    Packets: Sent = 4, Received = 0, Lost = 4 (100% loss),

PC>
```

PC3 的 ping 解释: 由于本地路由中没有目标地址为 192.168.1.11 的跳转条目, 因此收到回复目标主机不可到达; 而本地回复存在目标地址为 10.60.2.22 的跳转条目, 因此数据包能够发送到 10.60.2.22 节点, 但在数据包返回时, 由于其路由上没有目标地址为 172.16.3.33 的跳转条目, 因此回复失败, 所以收到的回复是请求超时, 即只是建立了单方面连接。



The screenshot shows the Packet Tracer interface for PC4. The top navigation bar includes tabs for Physical, Config, Desktop, and Custom Interface. The Desktop tab is active, displaying a Command Prompt window titled "Command Prompt". The prompt shows the execution of two ping commands. The first command is "ping 192.168.1.11", which results in four "Destination host unreachable" replies and a 100% loss of packets. The second command is "ping 10.60.2.22", which results in four successful replies with varying times and a 0% loss of packets. The prompt ends with "PC>|" indicating it is ready for the next command.

```
Packet Tracer PC Command Line 1.0
PC>ping 192.168.1.11

Pinging 192.168.1.11 with 32 bytes of data:

Reply from 118.18.4.254: Destination host unreachable.
Reply from 118.18.4.254: Destination host unreachable.
Reply from 118.18.4.254: Destination host unreachable.
Reply from 118.18.4.254: Destination host unreachable.

Ping statistics for 192.168.1.11:
    Packets: Sent = 4, Received = 0, Lost = 4 (100% loss),

PC>ping 10.60.2.22

Pinging 10.60.2.22 with 32 bytes of data:

Reply from 10.60.2.22: bytes=32 time=1ms TTL=126
Reply from 10.60.2.22: bytes=32 time=1ms TTL=126
Reply from 10.60.2.22: bytes=32 time=18ms TTL=126
Reply from 10.60.2.22: bytes=32 time=15ms TTL=126

Ping statistics for 10.60.2.22:
    Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),
    Approximate round trip times in milli-seconds:
        Minimum = 1ms, Maximum = 18ms, Average = 8ms

PC>|
```

PC4 的 ping 解释: 由于本地路由不存在目标地址为 192.168.1.11 的跳转条目, 因此收到的回复是目标主机不可到达; 而由于存在目标地址为 10.60.2.22 的跳转条目, 且在数据包返回时路由同样存在目标地址为 118.18.4.44 的跳转条目, 因此数据包顺利返回, 即 PC2-PC4 连通成功。

4.在路由器上配置静态 NAT。

```

-----
Router>en
Router#interface FastEthernet 0/0
      ^
% Invalid input detected at '^' marker.

Router#config
Router#configure t
Router#configure terminal
Enter configuration commands, one per line.  End with CNTL/Z.
Router(config)#interface FastEthernet 0/0
Router(config-if)#ip nat inside
Router(config-if)#exit
Router(config)#in
Router(config)#interface ser
Router(config)#interface serial 0
Router(config)#interface serial 0/0/0
Router(config-if)#ip nat outside
Router(config-if)#exit
Router(config)#

```

```

Router>
Router>
Router>en
Router#con
Router#config
Router#configure te
Router#configure terminal
Enter configuration commands, one per line.  End with CNTL/Z.
Router(config)#in
Router(config)#interface fa
Router(config)#interface fastEthernet 0/0
Router(config-if)#ip nat inside
Router(config-if)#exit
Router(config)#inte
Router(config)#interface ser
Router(config)#interface serial 0/0/0
Router(config-if)#ip nat outside
Router(config-if)#exit
Router(config)#

```

## 5.配置路由器 NAT 转换。

### Router2:

```

% Invalid input detected at '^' marker.

Router#config
Router#configure t
Enter configuration commands, one per line.  End with CNTL/Z.
Router(config)#ip nat inside source static 192.168.1.11 210.120.1.11
Router(config)#show ip nat tr
Router(config)#exit
Router#
%SYS-5-CONFIG_I: Configured from console by console

Router#
Router#show ip nat tr
Router#show ip nat translations
Pro Inside global      Inside local      Outside local      Outside global
--- 210.120.1.11        192.168.1.11      ---                ---
Router#

```

Copy

Paste

### Router3:

The screenshot shows the IOS Command Line Interface with tabs for Physical, Config, and CLI. The CLI tab is active, displaying the following commands and output:

```
Router#configure t
Enter configuration commands, one per line. End with CNTL/Z.
Router(config)#ip nat inside source static 172.16.3.33 218.100.3.33
Router(config)#exit
Router#
%SYS-5-CONFIG_I: Configured from console by console

Router#show ip nat tr
Router#show ip nat translations
Pro  Inside global      Inside local      Outside local      Outside global
---  218.100.3.33         172.16.3.33      ---                ---
Router#
```

Below the terminal window are 'Copy' and 'Paste' buttons.

6.使用 ping 命令检测连通性。

PC1:

ping 192.168.1.11

ping 210.120.1.11

ping 10.60.2.22

ping 172.16.3.33

ping 218.100.3.33

ping 118.18.4.44

结果:

PC>ping 192.168.1.11

Pinging 192.168.1.11 with 32 bytes of data:

Reply from 192.168.1.11: bytes=32 time=5ms TTL=128

Reply from 192.168.1.11: bytes=32 time=12ms TTL=128

Reply from 192.168.1.11: bytes=32 time=1ms TTL=128

Reply from 192.168.1.11: bytes=32 time=1ms TTL=128

Ping statistics for 192.168.1.11:

Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),

Approximate round trip times in milli-seconds:

Minimum = 1ms, Maximum = 12ms, Average = 4ms

这是自己 ping 自己，只要 TCP/IP 协议正常运载就能成功。

PC>ping 210.120.1.11

Pinging 210.120.1.11 with 32 bytes of data:

Reply from 192.168.1.254: Destination host unreachable.

Reply from 192.168.1.254: Destination host unreachable.

Reply from 192.168.1.254: Destination host unreachable.

Reply from 192.168.1.254: Destination host unreachable.

Ping statistics for 210.120.1.11:

Packets: Sent = 4, Received = 0, Lost = 4 (100% loss),

192.168.1.11 与外界连通时，将被 NAT 替换成 210.120.1.11（此时地址也是目标地址），此时再查询路由器中的路由表，由于不存在相关路由表项目，所以跳转失败，因此为目标主机不可到达。

PC>ping 10.60.2.22

Pinging 10.60.2.22 with 32 bytes of data:

Reply from 10.60.2.22: bytes=32 time=0ms TTL=127

Reply from 10.60.2.22: bytes=32 time=0ms TTL=127

Reply from 10.60.2.22: bytes=32 time=0ms TTL=127

Reply from 10.60.2.22: bytes=32 time=0ms TTL=127

Ping statistics for 10.60.2.22:

Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),

Approximate round trip times in milli-seconds:

Minimum = 0ms, Maximum = 0ms, Average = 0ms



由于 10.60.2.22 与 192.168.1.11 共同连接于同一个路由器，因此路由器可以直接进行转发，从而两者是连通的。

```
PC>ping 172.16.3.33\
```

```
PC>ping 172.16.3.33
```

Pinging 172.16.3.33 with 32 bytes of data:

Reply from 192.168.1.254: Destination host unreachable.

Reply from 192.168.1.254: Destination host unreachable.

Reply from 192.168.1.254: Destination host unreachable.

Reply from 192.168.1.254: Destination host unreachable.

Ping statistics for 172.16.3.33:

Packets: Sent = 4, Received = 0, Lost = 4 (100% loss),

192.168.1.11 在与外网连通时，会被替换为 210.120.1.11，但在其路由表中找不到相关的路由表项，因此反馈为目标主机不可到达。

```
PC>ping 218.100.3.33
```

Pinging 218.100.3.33 with 32 bytes of data:

Reply from 218.100.3.33: bytes=32 time=1ms TTL=126

Reply from 218.100.3.33: bytes=32 time=1ms TTL=126

Reply from 218.100.3.33: bytes=32 time=1ms TTL=126

Reply from 218.100.3.33: bytes=32 time=1ms TTL=126

Ping statistics for 218.100.3.33:

Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),

Approximate round trip times in milli-seconds:

Minimum = 1ms, Maximum = 1ms, Average = 1ms

192.168.1.11 在与外网连通时, 会被替换为 210.120.1.11, 然后查询其路由表, 刚好能够查找到目标地址为 218.100.3.33 的跳转条目, 因此数据包成功发送出去, 然后在数据包到达路由器时, 其同样将 218.100.3.33 替换为 172.16.3.33, 然后发送给 172.16.3.33, 其数据包的返回恰好相反, 路由器将 172.16.3.33 替换为 218.100.3.33, 然后发送给目标节点 210.120.1.11。因此 192.168.1.11 和 172.16.3.33 经过 NAT 之后实现了连通, 整个过程其实是借助了 210.120.1.11 和 218.100.3.33 两个互联网 IP 地址来实现的。

```
PC>ping 118.18.4.44
```

```
Pinging 118.18.4.44 with 32 bytes of data:
```

```
Reply from 118.18.4.44: bytes=32 time=1ms TTL=126
```

```
Reply from 118.18.4.44: bytes=32 time=1ms TTL=126
```

```
Reply from 118.18.4.44: bytes=32 time=1ms TTL=126
```

```
Reply from 118.18.4.44: bytes=32 time=17ms TTL=126
```

```
Ping statistics for 118.18.4.44:
```

```
Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),
```

```
Approximate round trip times in milli-seconds:
```

```
Minimum = 1ms, Maximum = 17ms, Average = 5ms
```

192.168.1.11 在与外网连通时, 会被替换为 210.120.1.11, 然后查询其路由表, 刚好能够查找到目标地址为 118.18.4.44 的跳转条目, 连通成功, 然后数据包返回时发送给目标节点 210.120.1.11, 路由器接收到数据包后替换目标地址为 192.168.1.11 实现数据发送。

```
PC>
```

```
PC2:
```

```
ping 192.168.1.11
```

```
ping 210.120.1.11
```

```
ping 10.60.2.22
```

ping 172.16.3.33

ping 218.100.3.33

ping 118.18.4.44

结果:

PC>ping 192.168.1.11

Pinging 192.168.1.11 with 32 bytes of data:

Reply from 192.168.1.11: bytes=32 time=0ms TTL=127

Reply from 192.168.1.11: bytes=32 time=0ms TTL=127

Reply from 192.168.1.11: bytes=32 time=0ms TTL=127

Reply from 192.168.1.11: bytes=32 time=16ms TTL=127

Ping statistics for 192.168.1.11:

Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),

Approximate round trip times in milli-seconds:

Minimum = 0ms, Maximum = 16ms, Average = 4ms

两个节点连接于同一个路由器，连接成功。

PC>ping 210.120.1.11

Pinging 210.120.1.11 with 32 bytes of data:

Reply from 10.60.2.254: Destination host unreachable.

Reply from 10.60.2.254: Destination host unreachable.

Request timed out.

Reply from 10.60.2.254: Destination host unreachable.

Ping statistics for 210.120.1.11:

Packets: Sent = 4, Received = 0, Lost = 4 (100% loss),

路由表中没有目标节点为 210.120.1.11 的跳转条目，因此跳转失败，目标主机不可到达。

```
PC>ping 10.60.2.22
```

Pinging 10.60.2.22 with 32 bytes of data:

Reply from 10.60.2.22: bytes=32 time=0ms TTL=128

Reply from 10.60.2.22: bytes=32 time=14ms TTL=128

Reply from 10.60.2.22: bytes=32 time=0ms TTL=128

Reply from 10.60.2.22: bytes=32 time=0ms TTL=128

Ping statistics for 10.60.2.22:

Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),

Approximate round trip times in milli-seconds:

Minimum = 0ms, Maximum = 14ms, Average = 3ms

自己 ping 自己，只要 TCP/IP 协议正常运载即可。

```
PC>ping 172.16.3.33
```

Pinging 172.16.3.33 with 32 bytes of data:

Reply from 10.60.2.254: Destination host unreachable.

Reply from 10.60.2.254: Destination host unreachable.

Reply from 10.60.2.254: Destination host unreachable.

Reply from 10.60.2.254: Destination host unreachable.

Ping statistics for 172.16.3.33:

Packets: Sent = 4, Received = 0, Lost = 4 (100% loss),

路由表中没有目标节点为 172.16.3.33 的跳转条目，因此跳转失败，目标主机不可到达。

```
PC>ping 218.100.3.33
```

Pinging 218.100.3.33 with 32 bytes of data:

Reply from 218.100.3.33: bytes=32 time=23ms TTL=126

Reply from 218.100.3.33: bytes=32 time=13ms TTL=126

Reply from 218.100.3.33: bytes=32 time=15ms TTL=126

Reply from 218.100.3.33: bytes=32 time=17ms TTL=126

Ping statistics for 218.100.3.33:

Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),

Approximate round trip times in milli-seconds:

Minimum = 13ms, Maximum = 23ms, Average = 17ms

路由表中存在目标地址为 218.100.3.33 的跳转条目，在数据包到达另一个路由器时，其将 218.100.3.33 替换为 172.16.3.33 然后转发给目标节点，在数据包返回时，再将 172.16.3.33 替换为 218.100.3.33 发送给 10.60.2.22，由于路由表中存在该跳转条目，因此数据包顺利返回，两个节点连通。

PC>ping 118.18.4.44

Pinging 118.18.4.44 with 32 bytes of data:

Reply from 118.18.4.44: bytes=32 time=22ms TTL=126

Reply from 118.18.4.44: bytes=32 time=15ms TTL=126

Reply from 118.18.4.44: bytes=32 time=15ms TTL=126

Reply from 118.18.4.44: bytes=32 time=13ms TTL=126

Ping statistics for 118.18.4.44:

Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),

Approximate round trip times in milli-seconds:

Minimum = 13ms, Maximum = 22ms, Average = 16ms

路由表中存在该跳转条目，数据包发送成功，对方路由器同样存在返回的跳转条目，因此返回成功，两者连通，这就是上面静态路由表的功劳。

PC>

PC3:

ping 192.168.1.11

ping 210.120.1.11

ping 10.60.2.22

ping 172.16.3.33

ping 218.100.3.33

ping 118.18.4.44

结果:

PC>ping 192.168.1.11

Pinging 192.168.1.11 with 32 bytes of data:

Reply from 172.16.3.254: Destination host unreachable.

Request timed out.

Reply from 172.16.3.254: Destination host unreachable.

Reply from 172.16.3.254: Destination host unreachable.

Ping statistics for 192.168.1.11:

Packets: Sent = 4, Received = 0, Lost = 4 (100% loss),

PC>ping 210.120.1.11

Pinging 210.120.1.11 with 32 bytes of data:

Reply from 210.120.1.11: bytes=32 time=4ms TTL=126

Reply from 210.120.1.11: bytes=32 time=15ms TTL=126

Reply from 210.120.1.11: bytes=32 time=2ms TTL=126

Reply from 210.120.1.11: bytes=32 time=1ms TTL=126

Ping statistics for 210.120.1.11:

Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),

Approximate round trip times in milli-seconds:

Minimum = 1ms, Maximum = 15ms, Average = 5ms

PC>ping 10.60.2.22

Pinging 10.60.2.22 with 32 bytes of data:

Reply from 10.60.2.22: bytes=32 time=21ms TTL=126

Reply from 10.60.2.22: bytes=32 time=16ms TTL=126

Reply from 10.60.2.22: bytes=32 time=16ms TTL=126

Reply from 10.60.2.22: bytes=32 time=3ms TTL=126

Ping statistics for 10.60.2.22:

Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),

Approximate round trip times in milli-seconds:

Minimum = 3ms, Maximum = 21ms, Average = 14ms

PC>ping 172.16.3.33

Pinging 172.16.3.33 with 32 bytes of data:

Reply from 172.16.3.33: bytes=32 time=13ms TTL=128

Reply from 172.16.3.33: bytes=32 time=3ms TTL=128

Reply from 172.16.3.33: bytes=32 time=2ms TTL=128

Reply from 172.16.3.33: bytes=32 time=0ms TTL=128

Ping statistics for 172.16.3.33:

Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),

Approximate round trip times in milli-seconds:

Minimum = 0ms, Maximum = 13ms, Average = 4ms

PC>ping 218.100.3.33

Pinging 218.100.3.33 with 32 bytes of data:

Reply from 172.16.3.254: Destination host unreachable.

Reply from 172.16.3.254: Destination host unreachable.

Reply from 172.16.3.254: Destination host unreachable.

Reply from 172.16.3.254: Destination host unreachable.

Ping statistics for 218.100.3.33:

Packets: Sent = 4, Received = 0, Lost = 4 (100% loss),

PC>ping 118.18.4.44

Pinging 118.18.4.44 with 32 bytes of data:

Reply from 118.18.4.44: bytes=32 time=0ms TTL=127

Reply from 118.18.4.44: bytes=32 time=0ms TTL=127

Reply from 118.18.4.44: bytes=32 time=0ms TTL=127

Reply from 118.18.4.44: bytes=32 time=0ms TTL=127

Ping statistics for 118.18.4.44:

Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),

Approximate round trip times in milli-seconds:



Minimum = 0ms, Maximum = 0ms, Average = 0ms

PC>

PC4:

ping 192.168.1.11

ping 210.120.1.11

ping 10.60.2.22

ping 172.16.3.33

ping 218.100.3.33

ping 118.18.4.44

结果:

PC>ping 192.168.1.11

Pinging 192.168.1.11 with 32 bytes of data:

Reply from 118.18.4.254: Destination host unreachable.

Reply from 118.18.4.254: Destination host unreachable.

Reply from 118.18.4.254: Destination host unreachable.

Reply from 118.18.4.254: Destination host unreachable.

Ping statistics for 192.168.1.11:

Packets: Sent = 4, Received = 0, Lost = 4 (100% loss),

PC>ping 210.120.1.11

Pinging 210.120.1.11 with 32 bytes of data:

Reply from 210.120.1.11: bytes=32 time=3ms TTL=126

Reply from 210.120.1.11: bytes=32 time=1ms TTL=126

Reply from 210.120.1.11: bytes=32 time=15ms TTL=126

Reply from 210.120.1.11: bytes=32 time=1ms TTL=126

Ping statistics for 210.120.1.11:

Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),

Approximate round trip times in milli-seconds:

Minimum = 1ms, Maximum = 15ms, Average = 5ms

PC>ping 10.60.2.22

Pinging 10.60.2.22 with 32 bytes of data:

Reply from 10.60.2.22: bytes=32 time=2ms TTL=126

Reply from 10.60.2.22: bytes=32 time=2ms TTL=126

Reply from 10.60.2.22: bytes=32 time=3ms TTL=126

Reply from 10.60.2.22: bytes=32 time=2ms TTL=126

Ping statistics for 10.60.2.22:

Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),

Approximate round trip times in milli-seconds:

Minimum = 2ms, Maximum = 3ms, Average = 2ms

PC>ping 172.16.3.33

Pinging 172.16.3.33 with 32 bytes of data:

Reply from 172.16.3.33: bytes=32 time=0ms TTL=127

Reply from 172.16.3.33: bytes=32 time=0ms TTL=127

Reply from 172.16.3.33: bytes=32 time=0ms TTL=127

Reply from 172.16.3.33: bytes=32 time=0ms TTL=127

Ping statistics for 172.16.3.33:

Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),

Approximate round trip times in milli-seconds:

Minimum = 0ms, Maximum = 0ms, Average = 0ms

PC>ping 218.100.3.33

Pinging 218.100.3.33 with 32 bytes of data:

Reply from 118.18.4.254: Destination host unreachable.

Reply from 118.18.4.254: Destination host unreachable.

Reply from 118.18.4.254: Destination host unreachable.

Reply from 118.18.4.254: Destination host unreachable.

Ping statistics for 218.100.3.33:

Packets: Sent = 4, Received = 0, Lost = 4 (100% loss),

PC>ping 118.18.4.44

Pinging 118.18.4.44 with 32 bytes of data:

Reply from 118.18.4.44: bytes=32 time=14ms TTL=128

Reply from 118.18.4.44: bytes=32 time=17ms TTL=128

Reply from 118.18.4.44: bytes=32 time=18ms TTL=128

Reply from 118.18.4.44: bytes=32 time=12ms TTL=128

Ping statistics for 118.18.4.44:

Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),

Approximate round trip times in milli-seconds:

Minimum = 12ms, Maximum = 18ms, Average = 15ms

PC>

【分析讨论】