CS 305 Lab Tutorial
Lecture 12 NAT, RIP, OSPF

Dept. Computer Science and Engineering
Southern University of Science and Technology

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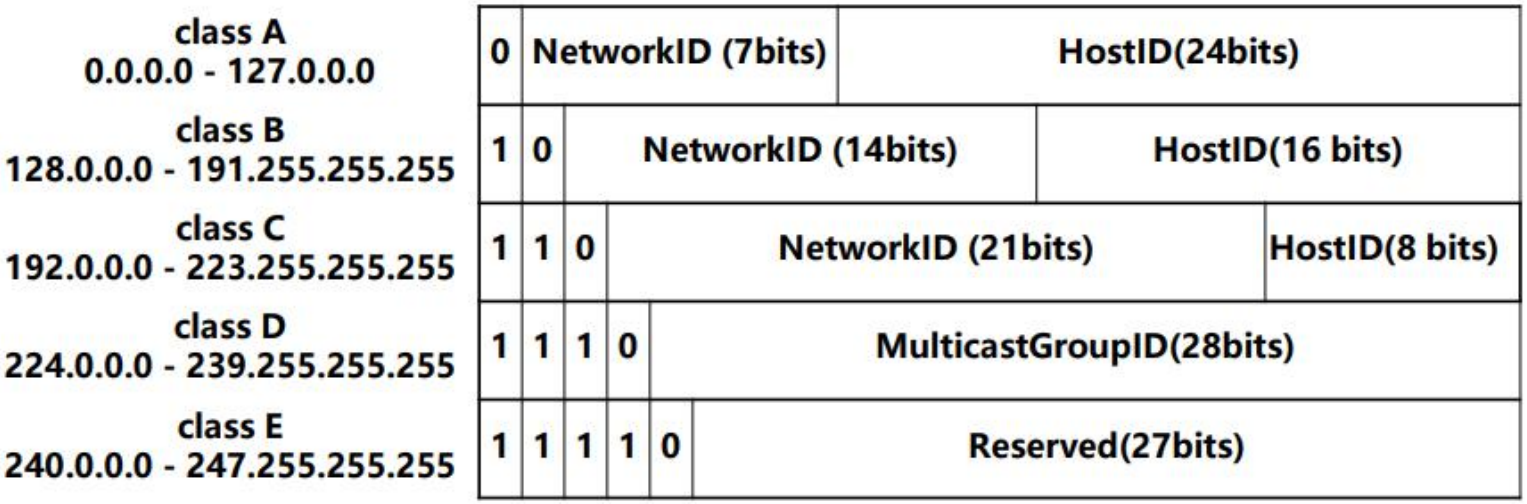
Thanks to Wei Wang

Topic

- IPv4 Addressing
- NAT
  - Static conversion
  - Dynamic conversion
  - NAPT
- Routing Protocol
  - RIP
  - OSPF
- Practice
  - Build network on simulator
  - Configure
  - Test

Part A. IPv4 Addressing (1)

- Class A/B/C network address assignment
  - class A, class B, class C
  - parts of this were eventually defined (MSB '1110') for use with IPv4 multicast and parts are still reserved



IPv4 Addressing (2)

- Major problems of class A/B/C network numbers:
  - Exhaustion of the Class B network address space.
  - Growth of routing tables in Internet routers beyond the ability of current software, hardware, and people to effectively manage.
  - Eventual exhaustion of the 32-bit IPv4 address space.
- CDIR: Classless Inter-domain Routing
  - "classless“
  - hierarchical blocks of IP addresses (referred to as prefixes)
  - /16, /24, ……

https://www.rfc-editor.org/rfc/rfc4632.txt

IPv4 Addressing(3)

- Public: require IP addresses that are globally unambiguous
  - hosts that need network layer access outside the enterprise
- Private: may be ambiguous between enterprises
  - hosts that do not require access to hosts in other enterprises or the Internet at large
  - hosts that need access to a limited set of outside services which can be handled by mediating gateways
  - Private address space
    - 10.0.0.0 - 10.255.255.255 (10/8 prefix)
    - 172.16.0.0 - 172.31.255.255 (172.16/12 prefix)
    - 192.168.0.0 - 192.168.255.255 (192.168/16 prefix)

https://www.rfc-editor.org/rfc/rfc1918.txt

Part B.
NAT - Network Address Translator

- The need for IP Address translation arises when a network's internal IP addresses cannot be used outside the network either for privacy reasons or because they are invalid for use outside the network.
- Traditional NAT, provide a mechanism to connect a realm with private addresses to an external realm with globally unique registered addresses.
  - Basic **Network Address Translation** or Basic **NAT**: IP addresses are mapped from one group to another.
  - **Network Address Port Translation**, or **NAPT**: many network addresses and their TCP/UDP ports are translated into a single network address and its TCP/UDP ports.

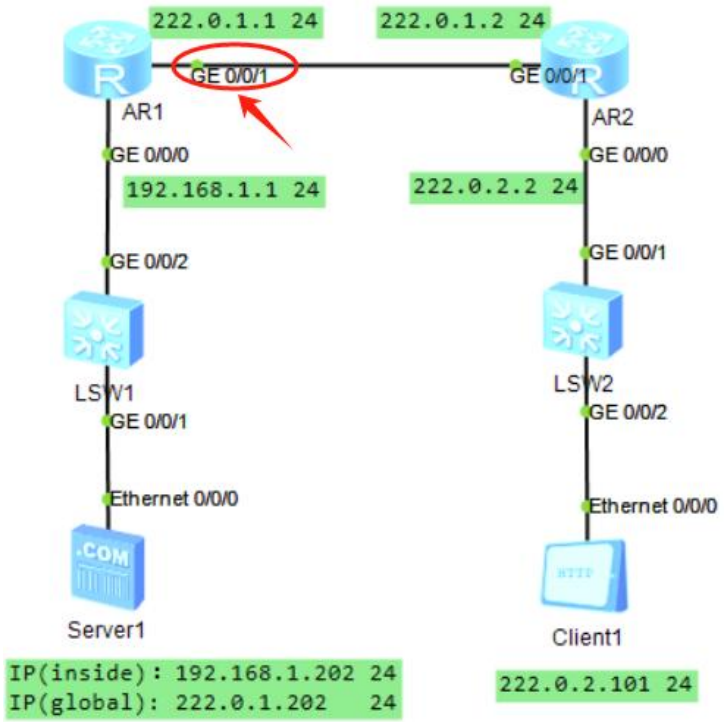
https://www.rfc-editor.org/rfc/rfc3022.txt

NAT(Static conversion)

The mapping relationship of IP addresses is one-to-one and remains unchanged.

- With the help of static conversion, the access of external network to some special servers in internal network can be realized.

- **Demo1 : NAT(Static conversion) -1**
  - The current server has a private address (192.168.1.202/24) and a global address (222.0.1.202/24). In order to hide the private address of the server, it is necessary to perform static address mapping on the router of the network where the server is located.
  - Configuration steps on eNSP:
    - step0. Complete the basic configuration of the network, including the basic configuration of Client1 and Server1, interface configuration on AR1 and AR2, and static routing configuration(route information about how to network 222.0.2.0/24) on AR1.
    - step1. **Determine the interface to be used for NAT:** GE 0/0/1 of AR1(The address of this interface is in the same network as the global address converted by NAT)
    - step2. **Apply the NAT static conversion configuration on the interface** :
      - **nat static global <global address> inside <private address> [netmask <netmask of private address 255.255.255.255>]**

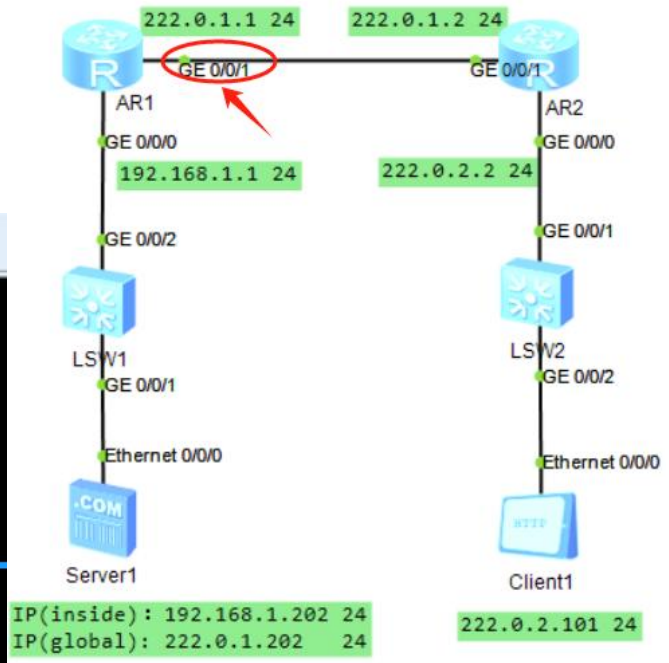


e.g.
nat static global 222.0.1.202 inside 192.168.1.202 netmask 255.255.255.255

Demo1-NAT(Static conversion)-2

The following figure shows the configuration on the two interfaces of AR1 on the network where the server is located.

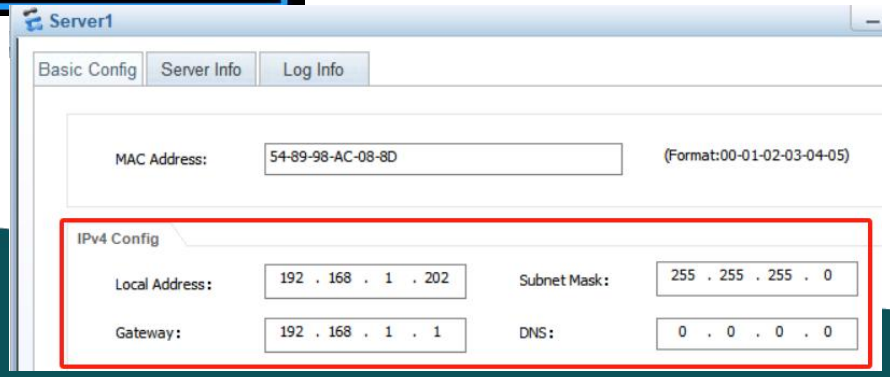
Note that for the convenience of testing NAT, the routing to the network(192.168.1.0 / 24) is not configured on AR2, and only direct routing items are available on AR2.



AR1

```
[Huawei-GigabitEthernet0/0/0]dis this
[V200R003C00]
#
interface GigabitEthernet0/0/0
 ip address 192.168.1.1 255.255.255.0
#
return
[Huawei-GigabitEthernet0/0/0]int gi0/0/1
[Huawei-GigabitEthernet0/0/1]dis this
[V200R003C00]
#
interface GigabitEthernet0/0/1
 ip address 222.0.1.1 255.255.255.0
 nat static global 222.0.1.202 inside 192.168.1.202 netmask 255.255.255.255
#
return
```

Server1 is configured with private address: 192.168.1.202 24



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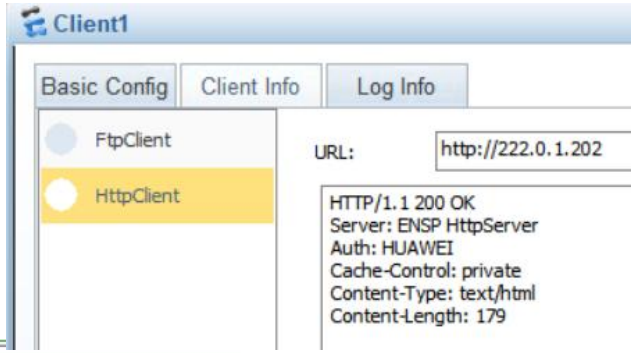
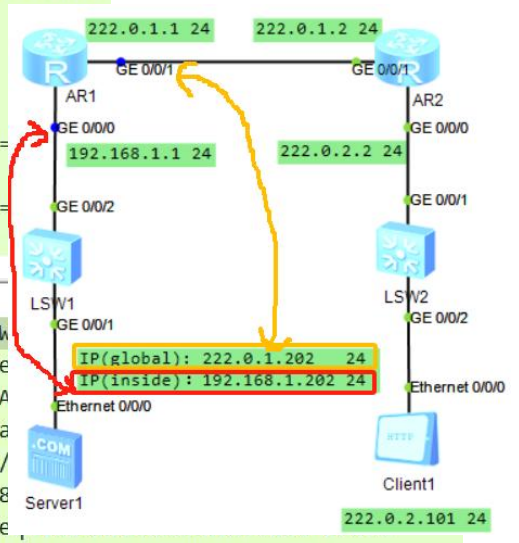
Demo1-NAT(Static conversion)-3

Capture packets on the GE0/0/0 and GE0/0/1 of AR1:

- Initiate HTTP access to Server1 on Client1
- The packets sent and received on the **GE0/0/1** are the packets exchanged between the global addresses of Server1 (**222.0.1.202**) and Client1.
- The packets sent and received on the **GE0/0/0** are the packets exchanged between the private addresses of Server1 (**192.168.1.202**) and Client1.



Source	Protocol	Destination	Length	Info
222.0.2.101	TCP	222.0.1.202	58	2050 → 80 [SYN] Seq=0 Win=8192 Len=0 MSS=1460
222.0.1.202	TCP	222.0.2.101	58	80 → 2050 [SYN, ACK] Seq=0 Ack=1 Win=8192 Len=0 MSS=1460
222.0.2.101	TCP	222.0.1.202	54	2050 → 80 [ACK] Seq=1 Ack=1 Win=8192 Len=0
222.0.2.101	HTTP	222.0.1.202	211	GET / HTTP/1.1 Continuation
222.0.1.202	HTTP	222.0.2.101	361	HTTP/1.1 200 OK (text/html)
222.0.2.101	TCP	222.0.1.202	54	2050 → 80 [ACK] Seq=158 Ack=308 Win=7885 Len=0
222.0.2.101	TCP	222.0.1.202	54	2050 → 80 [FIN, ACK] Seq=158 Ack=308 Win=7885 Len=
222.0.1.202	TCP	222.0.2.101	54	80 → 2050 [ACK] Seq=308 Ack=159 Win=8034 Len=0
222.0.1.202	TCP	222.0.2.101	54	80 → 2050 [FIN, ACK] Seq=308 Ack=159 Win=8034 Len=
222.0.2.101	TCP	222.0.1.202	54	2050 → 80 [ACK] Seq=159 Ack=309 Win=7884 Len=0

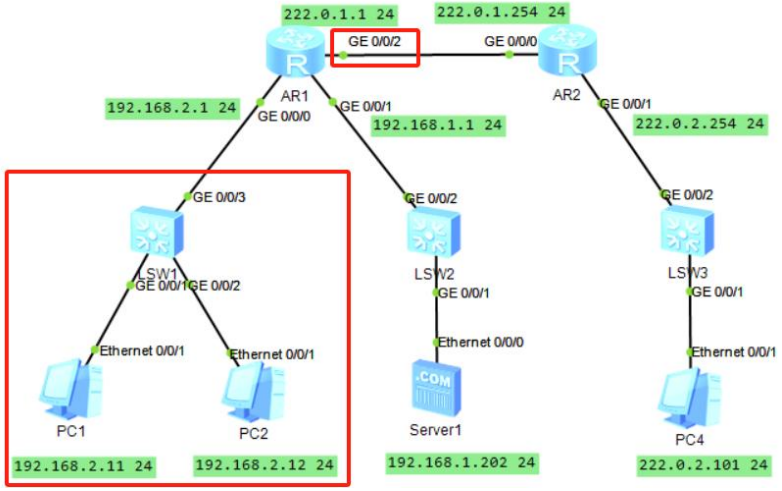


Source	Protocol	Destination	Length	Info
222.0.2.101	TCP	192.168.1.202	58	2050 → 80 [SYN] Seq=0 W
192.168.1.202	TCP	222.0.2.101	58	80 → 2050 [SYN, ACK] Se
222.0.2.101	TCP	192.168.1.202	54	2050 → 80 [ACK] Seq=1 A
222.0.2.101	HTTP	192.168.1.202	211	GET / HTTP/1.1 Continua
192.168.1.202	HTTP	222.0.2.101	361	HTTP/1.1 200 OK (text/
222.0.2.101	TCP	192.168.1.202	54	2050 → 80 [ACK] Seq=158
222.0.2.101	TCP	192.168.1.202	54	2050 → 80 [FIN, ACK] Se
192.168.1.202	TCP	222.0.2.101	54	80 → 2050 [ACK] Seq=308 Ack=159 Win=8034 Len=0
192.168.1.202	TCP	222.0.2.101	54	80 → 2050 [FIN, ACK] Seq=308 Ack=159 Win=8034 Len=0
222.0.2.101	TCP	192.168.1.202	54	2050 → 80 [ACK] Seq=159 Ack=309 Win=7884 Len=0

NAT(Dynamic conversion)

NAT(Dynamic conversion): The mapping relationship of IP addresses is uncertain and random.

- It is suitable for scenarios where the number of hosts accessing the Internet at the same time in an internal network is less than the number of IP addresses in the configured legitimate address.

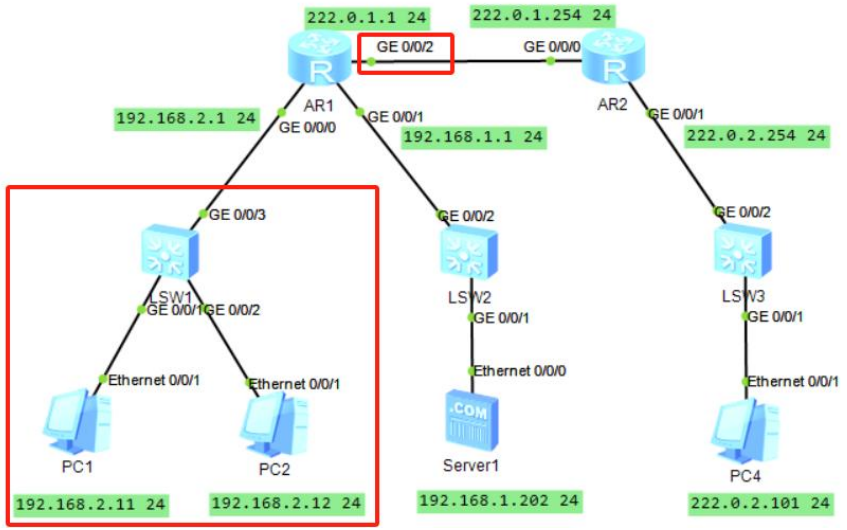


- **Demo2. NAT(Dynamic conversion) -1**
  - Requirement:
    a group of private address(192.168.2.1 - 192.168.2.254)
    share a group of global address(222.0.1. 110-222.0.1.120)

  - Configuration steps about NAT(Dynamic conversion) on eNSP:
    - step0. **Determint the router and the interface which applies the NAT**(Dynamic conversion)
    - step1. **Create a "nat address-group" to specify the range of the global address group**
      - command: **nat address-group** <group-number> <x.x.x.x start-address> <x.x.x.x end-address>
    - step2. **Create an "acl" and specify the range of the private adress group**
      - command: **acl** < acl-number>
      - command: **rule** <rule-number> **permit source**<private address-start address> <wildcast mask>
    - step3. **Switch to Interface(which NAT dynamic conversion would be applied) Configuration View , applies the NAT configuration**
      - command: interface <interface type and number>
      - command: **nat outbound** <acl -number> **address-group** <group-number> **no-pat**

Demo2-NAT(Dynamic conversion)-2

The details about the configurations related to NAT(Dynamic conversion) are as follows:

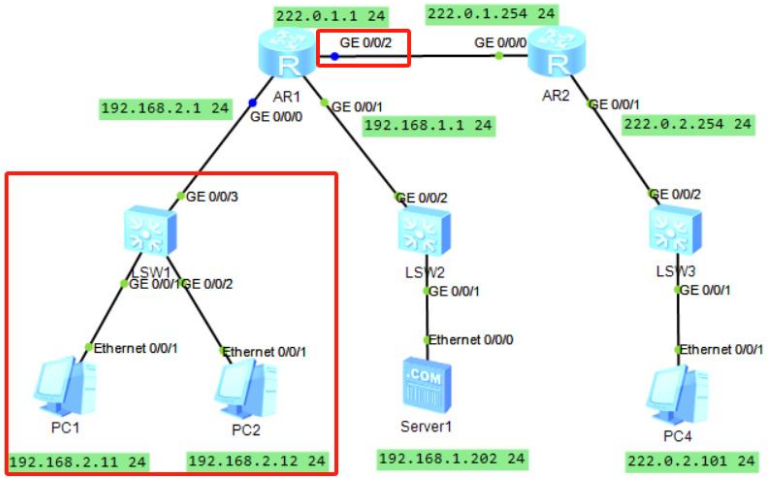



```
[AR1]dis nat address-group

 NAT Address-Group Information:
 --------------------------------------
 Index    Start-address       End-address

 2          222.0.1.110       222.0.1.120
 --------------------------------------
  Total : 1
```

```
[AR1]acl 2000
[AR1-acl-basic-2000]dis this
[V200R003C00]
#
acl number 2000
 rule 5 permit source 192.168.2.0 0.0.0.255
#
return
[AR1-acl-basic-2000]
```

```
AR1-GigabitEthernet0/0/2 dis this
[V200R003C00]
#
interface GigabitEthernet0/0/2
 ip address 222.0.1.1 255.255.255.0
 nat outbound 2000 address-group 2 no-pat
#
return
```

Demo2-NAT(Dynamic conversion)-3



After the configuration is done, initiate a "**ping**" test from PC1 to PC4, capturing packets at GE0/0/0 and GE0/0/2 on AR1 respectively

Packets captured on **GE0/0/0** are as follows: **PC1** communicates with PC4 by using the same private address(**192.168.2.11**)

Source	Protocol	Destination	Leng	Info
192.168.2.11	ICMP	222.0.2.101	74	Echo (ping) request id=0x988a,
222.0.2.101	ICMP	192.168.2.11	74	Echo (ping) reply id=0x988a,
192.168.2.11	ICMP	222.0.2.101	74	Echo (ping) request id=0x998a,
222.0.2.101	ICMP	192.168.2.11	74	Echo (ping) reply id=0x998a,
192.168.2.11	ICMP	222.0.2.101	74	Echo (ping) request id=0x9a8a,
222.0.2.101	ICMP	192.168.2.11	74	Echo (ping) reply id=0x9a8a,
192.168.2.11	ICMP	222.0.2.101	74	Echo (ping) request id=0x9b8a,
222.0.2.101	ICMP	192.168.2.11	74	Echo (ping) reply id=0x9b8a,
192.168.2.11	ICMP	222.0.2.101	74	Echo (ping) request id=0x9c8a,
222.0.2.101	ICMP	192.168.2.11	74	Echo (ping) reply id=0x9c8a,

PC1

Basic Config | Command | MCPacket | UdpPacket | Console

```
PC>ping 222.0.2.101

Ping 222.0.2.101: 32 data bytes, Press Ctrl_C to brea
From 222.0.2.101: bytes=32 seq=1 ttl=126 time=63 ms
From 222.0.2.101: bytes=32 seq=2 ttl=126 time=78 ms
From 222.0.2.101: bytes=32 seq=3 ttl=126 time=94 ms
From 222.0.2.101: bytes=32 seq=4 ttl=126 time=78 ms
From 222.0.2.101: bytes=32 seq=5 ttl=126 time=62 ms
```

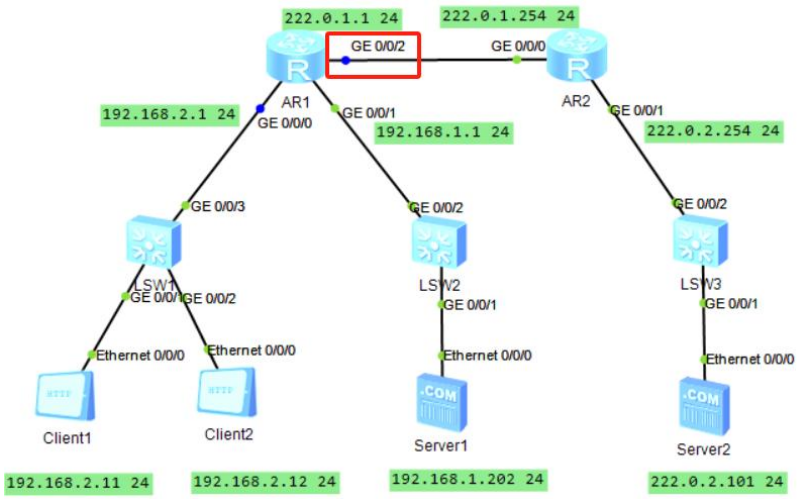
Packets captured on **GE0/0/2** are as follows: **PC1** communicates with PC4 by using the different global addressess (**222.0.1.110 - 222.0.1.114**)

Source	Protocol	Destination	Len	Info
222.0.1.110	ICMP	222.0.2.101	74	Echo (ping) request id=0x988a,
222.0.2.101	ICMP	222.0.1.110	74	Echo (ping) reply id=0x988a,
222.0.1.111	ICMP	222.0.2.101	74	Echo (ping) request id=0x998a,
222.0.2.101	ICMP	222.0.1.111	74	Echo (ping) reply id=0x998a,
222.0.1.112	ICMP	222.0.2.101	74	Echo (ping) request id=0x9a8a,
222.0.2.101	ICMP	222.0.1.112	74	Echo (ping) reply id=0x9a8a,
222.0.1.113	ICMP	222.0.2.101	74	Echo (ping) request id=0x9b8a,
222.0.2.101	ICMP	222.0.1.113	74	Echo (ping) reply id=0x9b8a,
222.0.1.114	ICMP	222.0.2.101	74	Echo (ping) request id=0x9c8a,
222.0.2.101	ICMP	222.0.1.114	74	Echo (ping) reply id=0x9c8a,

NAPT(Network Address Port Translation)

NAPT: many network addresses and their TCP/UDP ports are translated into a single network address and its TCP/UDP ports.

- NAPT allow multiple hosts to share a single public IP address, distinguished by port numbers at the transport layer, commonly used in home or small business networks.

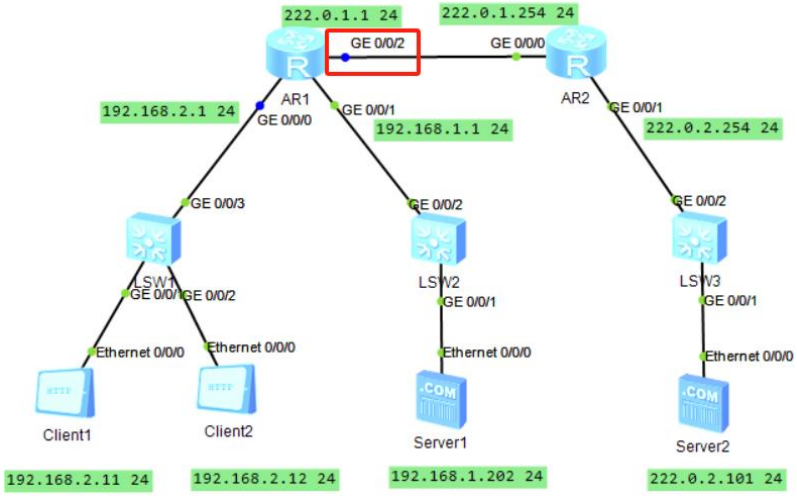


- **Demo3. NAT(Dynamic conversion) -1**
  - Requirement:
    a group of private address(192.168.2.11, 192.168.2.12, ...)
    share a global address(222.0.1. 101)

  - Configuration steps about NAPT on eNSP:
    - step0. **Determint the router and the interface which applies the NAPT**
    - step1. **Create a "nat address-group" to specify the global address**
      - command: **nat address-group** <group-number> <x.x.x.x the global address> <x.x.x.x the global address>
    - step2. **Create an "acl" and specify the range of the private adress group**
      - command: **acl** < acl-number>
      - command: **rule** <rule-number> **permit source** <private address-start address> <wildcast mask>
    - step3. **Switch to Interface(which NAPT would be applied) Configuration View , applies the NAPT configuration**
      - command: interface <interface type and number>
      - command: **nat outbound** <acl -number> **address-group** <group-number>

Demo3-NAPT(2)

NAPT: In demo3 here, map 192.168.1.11, 192.168.1.12, and other PCs with the same high 28 bits of the IP address as 192.168.1.11 to the same global address 222.0.1.101 (distinguished by different ports)




```
[AR1]nat address-group 2 ?
  IP_ADDR<X.X.X.X>  Start address
[AR1]nat address-group 2 222.0.1.101 ?
  IP_ADDR<X.X.X.X>  End address
[AR1]nat address-group 2 222.0.1.101 222.0.1.101
[AR1]
```

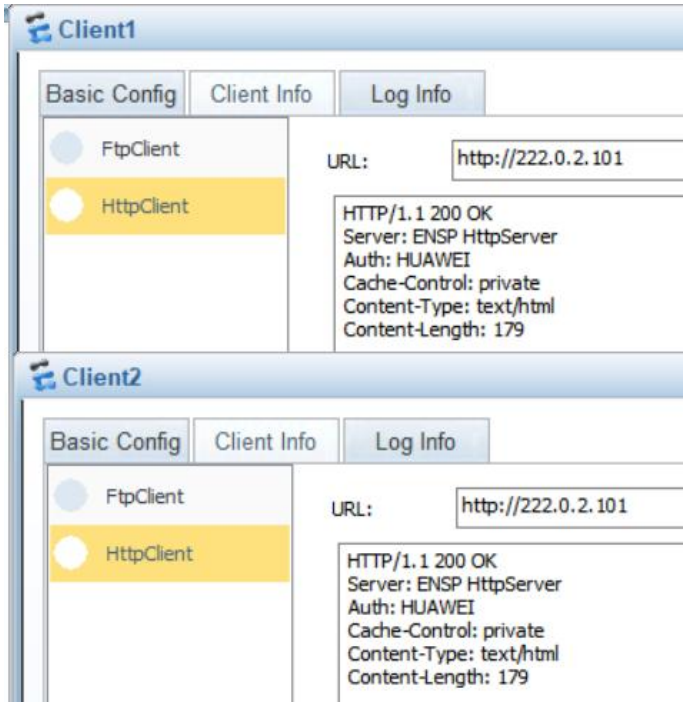
```
[AR1]acl 2000
[AR1-acl-basic-2000]rule 5 permit source 192.168.2.11 ?
  IP_ADDR<X.X.X.X>  Wildcard of source
  0                 Wildcard bits : 0.0.0.0 ( a host )
[AR1-acl-basic-2000]rule 5 permit source 192.168.2.11 0.0.0.15
```

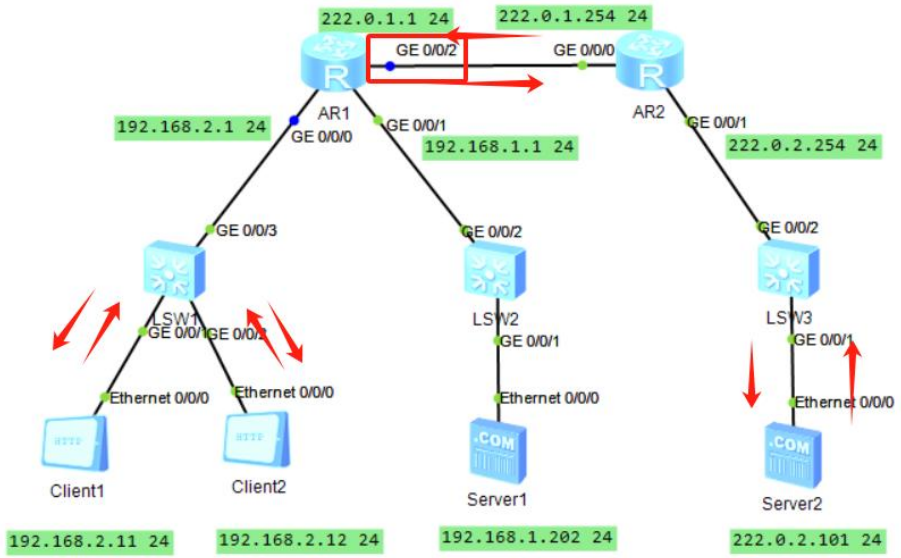
```
[AR1-GigabitEthernet0/0/2]nat outbound ?
  INTEGER<2000-3999>  Apply basic or advanced ACL
[AR1-GigabitEthernet0/0/2]nat outbound 2000 ?
  address-group  IP address-group of NAT
  interface      Specify the interface
  <cr>           Please press ENTER to execute command
[AR1-GigabitEthernet0/0/2]nat outbound 2000 address-group ?
  INTEGER<0-7>  Index of address-group
[AR1-GigabitEthernet0/0/2]nat outbound 2000 address-group 2 ?
  no-pat  Not use PAT
  <cr>    Please press ENTER to execute command
[AR1-GigabitEthernet0/0/2]nat outbound 2000 address-group 2
[AR1-GigabitEthernet0/0/2]
```

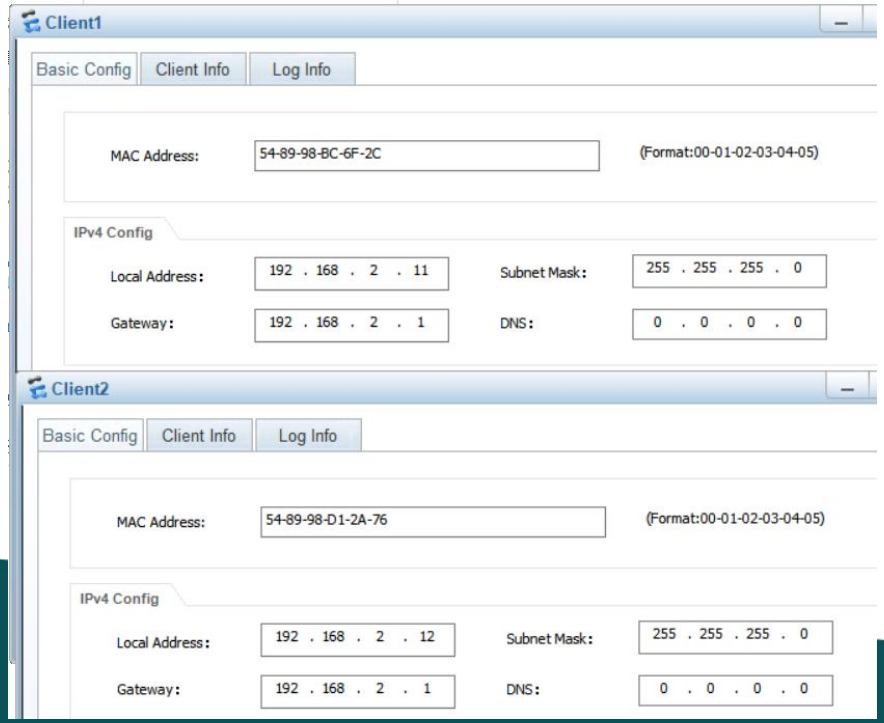
Q: If add new Clients to the subnet(192.168.1.0/24), which private IP addresses could be assigned to these Clients to share the global address(222.0.1.101) by using the existing NAPT mapping?

Demo3-NAPT(3)

After the NAPT configuration is done, Client1 and Client2(both Client1 and Client2 are configured with private addresses) initiate HTTP access to Server2.







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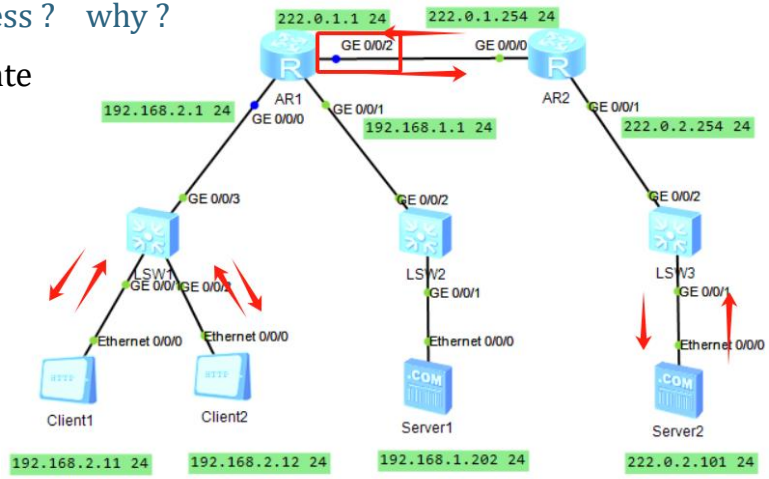
Demo3-NAPT(4)

Q: Is NAPT suitable for multiple servers sharing the same global address ? why ?

Client1 and Client2(both Client1 and Client2 are configured with private addresses) initiate HTTP access to Server2.



Packets captured on AR1's **GE0/0/0** <----------

Source	Protocol	Destination	Length	Info
192.168.2.11	TCP	222.0.2.101	58	2050 → 80 [SYN] Seq=0 Win=8
222.0.2.101	TCP	192.168.2.11	58	80 → 2050 [SYN, ACK] Seq=0
192.168.2.11	TCP	222.0.2.101	54	2050 → 80 [ACK] Seq=1 Ack=1
192.168.2.11	HTTP	222.0.2.101	211	GET / HTTP/1.1 Continuation
222.0.2.101	TCP	192.168.2.11	54	80 → 2050 [ACK] Seq=1 Ack=1
222.0.2.101	HTTP	192.168.2.11	361	HTTP/1.1 200 OK (text/html)
192.168.2.11	TCP	222.0.2.101	54	2050 → 80 [ACK] Seq=158 Ack
192.168.2.11	TCP	222.0.2.101	54	2050 → 80 [FIN, ACK] Seq=15
222.0.2.101	TCP	192.168.2.11	54	80 → 2050 [ACK] Seq=308 Ack
222.0.2.101	TCP	192.168.2.11	54	80 → 2050 [FIN, ACK] Seq=30
192.168.2.11	TCP	222.0.2.101	54	2050 → 80 [ACK] Seq=159 Ack
192.168.2.12	TCP	222.0.2.101	58	2050 → 80 [SYN] Seq=0 Win=8
222.0.2.101	TCP	192.168.2.12	58	80 → 2050 [SYN, ACK] Seq=0
192.168.2.12	TCP	222.0.2.101	54	2050 → 80 [ACK] Seq=1 Ack=1
192.168.2.12	HTTP	222.0.2.101	211	GET / HTTP/1.1 Continuation
222.0.2.101	HTTP	192.168.2.12	361	HTTP/1.1 200 OK (text/html)
192.168.2.12	TCP	222.0.2.101	54	2050 → 80 [ACK] Seq=158 Ack
192.168.2.12	TCP	222.0.2.101	54	2050 → 80 [FIN, ACK] Seq=15
222.0.2.101	TCP	192.168.2.12	54	80 → 2050 [ACK] Seq=308 Ack
222.0.2.101	TCP	192.168.2.12	54	80 → 2050 [FIN, ACK] Seq=30
192.168.2.12	TCP	222.0.2.101	54	2050 → 80 [ACK] Seq=159 Ack

Packets captured on AR1's **GE0/0/2**---------->

- private address **192.168.2.11** with port 2050 is mapped to global address **222.0.1.101** with port **552**
- private address **192.168.2.12** with port 2050 is mapped to global address **222.0.1.101** with port **808**

Source	Protocol	Destination	Length	Info
222.0.1.101	TCP	222.0.2.101	58	552 → 80 [SYN] Seq=0 Win=8192 L
222.0.2.101	TCP	222.0.1.101	58	80 → 552 [SYN, ACK] Seq=0 Ack=1
222.0.1.101	TCP	222.0.2.101	54	552 → 80 [ACK] Seq=1 Ack=1 Win=
222.0.1.101	HTTP	222.0.2.101	211	GET / HTTP/1.1 Continuation
222.0.2.101	TCP	222.0.1.101	54	80 → 552 [ACK] Seq=1 Ack=158 Wi
222.0.2.101	HTTP	222.0.1.101	361	HTTP/1.1 200 OK (text/html)
222.0.1.101	TCP	222.0.2.101	54	552 → 80 [ACK] Seq=158 Ack=308
222.0.1.101	TCP	222.0.2.101	54	552 → 80 [FIN, ACK] Seq=158 Ack
222.0.2.101	TCP	222.0.1.101	54	80 → 552 [ACK] Seq=308 Ack=159
222.0.2.101	TCP	222.0.1.101	54	80 → 552 [FIN, ACK] Seq=308 Ack
222.0.1.101	TCP	222.0.2.101	54	552 → 80 [ACK] Seq=159 Ack=309
222.0.1.101	TCP	222.0.2.101	58	808 → 80 [SYN] Seq=0 Win=8192 L
222.0.2.101	TCP	222.0.1.101	58	80 → 808 [SYN, ACK] Seq=0 Ack=1
222.0.1.101	TCP	222.0.2.101	54	808 → 80 [ACK] Seq=1 Ack=1 Win=
222.0.1.101	HTTP	222.0.2.101	211	GET / HTTP/1.1 Continuation
222.0.2.101	HTTP	222.0.1.101	361	HTTP/1.1 200 OK (text/html)
222.0.1.101	TCP	222.0.2.101	54	808 → 80 [ACK] Seq=158 Ack=308
222.0.1.101	TCP	222.0.2.101	54	808 → 80 [FIN, ACK] Seq=158 Ack
222.0.2.101	TCP	222.0.1.101	54	80 → 808 [ACK] Seq=308 Ack=159
222.0.2.101	TCP	222.0.1.101	54	80 → 808 [FIN, ACK] Seq=308 Ack
222.0.1.101	TCP	222.0.2.101	54	808 → 80 [ACK] Seq=159 Ack=309

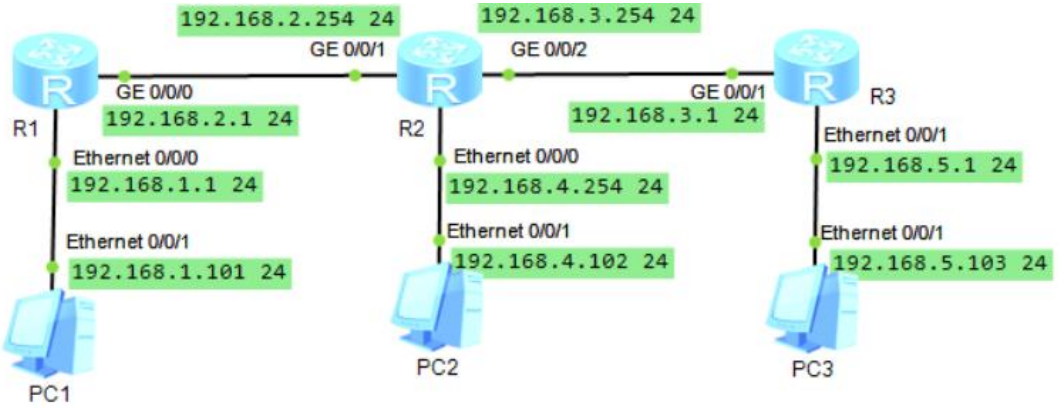
Part C.
RIP - Routing Information Protocol

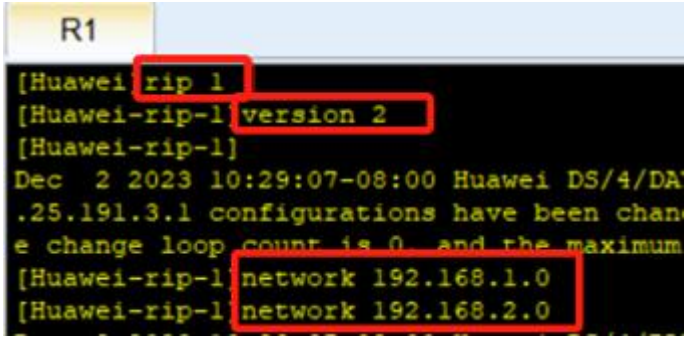
- Distance Vector or Ford-Fulkerson algorithms
- This protocol is most useful as an "interior gateway protocol“ (IGP)
- represents the metric as a sum of "costs" for individual hops
- update:
  - every gateway that participates in routing sends an update message to all its neighbors once every **30** seconds
  - wait for **180** seconds before timing out a route
- version:
  - RIP V1 (broadcase, No authentication, ...)
  - RIP V2 (multicast, authentication, ...)

https://www.rfc-editor.org/rfc/rfc1058.txt

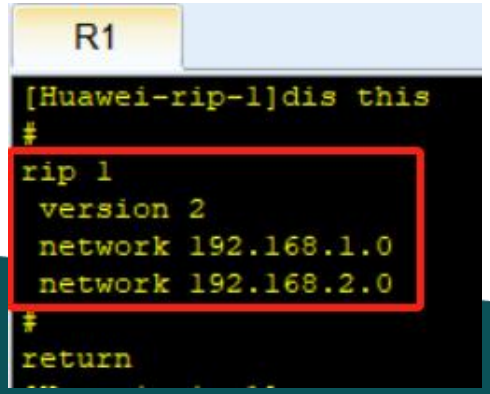
RIP(1)

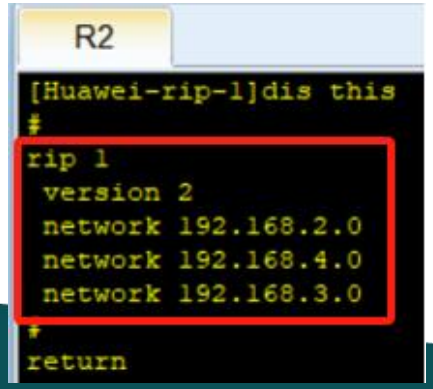
- Configuration on eNSP
  - 0. interface configuration on the interface of Router
  - 1. start rip configuration
    - command: **rip** 1
  - 2. specify the rip version
    - command: **version** <version number>
  - 3. add the network info which is connect directly by the Router
    - command: **network** <network ID>

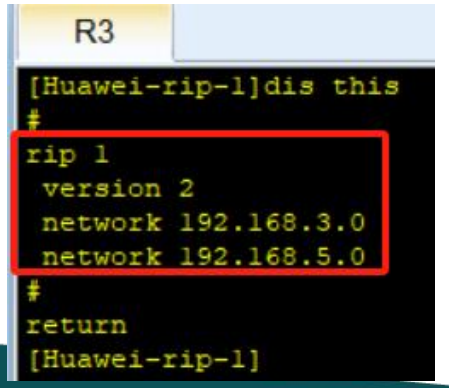




The configurations about RIP in this demo are as following:

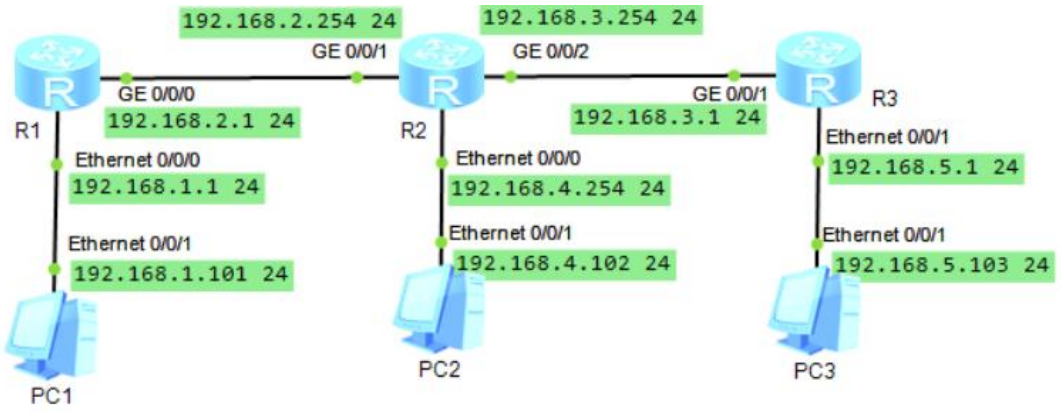






RIP(2)

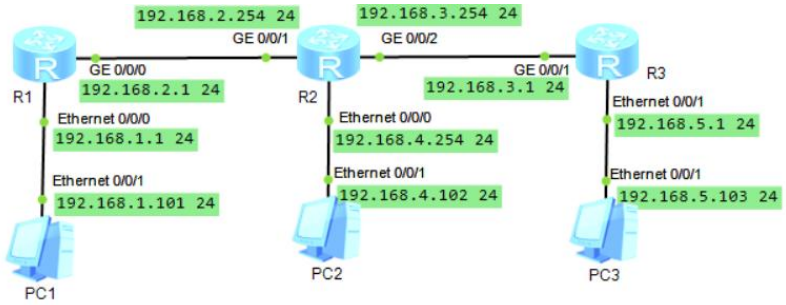
- After the configuration on RIP is done, the routing-table of R1 is as following:
  - the routing to 192.168.3.0/24, 192.168.4.0/24, 192.168.5.0/24 are generated by RIP
  - Cost is determined by the number of routers on the routing path



R1

```
[Huawei]dis 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

        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
    192.168.1.0/24  Direct  0    0           D   192.168.1.1     Ethernet0/0/0
    192.168.1.1/32  Direct  0    0           D   127.0.0.1       Ethernet0/0/0
    192.168.2.0/24  Direct  0    0           D   192.168.2.1     GigabitEthernet
0/0/0
    192.168.2.1/32  Direct  0    0           D   127.0.0.1       GigabitEthernet
0/0/0
    192.168.3.0/24  RIP     100  1           D   192.168.2.254   GigabitEthernet
0/0/0
    192.168.4.0/24  RIP     100  1           D   192.168.2.254   GigabitEthernet
0/0/0
    192.168.5.0/24  RIP     100  2           D   192.168.2.254   GigabitEthernet
0/0/0
```

RIP(3)



the routing-table of R2:

---------->

the routing-table of R3:

---------->

R2

```
[Huawei dis ip routing-table
Route Flags: R - relay, D - download to fib
------------------------------------------------------------------------------
Routing Tables: Public
         Destinations : 10        Routes : 10

Destination/Mask    Proto   Pre  Cost      Flags NextHop         Interface

      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
    192.168.1.0/24  RIP     100  1           D   192.168.2.1     GigabitEthernet
0/0/1
    192.168.2.0/24  Direct  0    0           D   192.168.2.254   GigabitEthernet
0/0/1
  192.168.2.254/32  Direct  0    0           D   127.0.0.1       GigabitEthernet
0/0/1
    192.168.3.0/24  Direct  0    0           D   192.168.3.254   GigabitEthernet
0/0/2
  192.168.3.254/32  Direct  0    0           D   127.0.0.1       GigabitEthernet
0/0/2
    192.168.4.0/24  Direct  0    0           D   192.168.4.254   Ethernet0/0/0
  192.168.4.254/32  Direct  0    0           D   127.0.0.1       Ethernet0/0/0
    192.168.5.0/24  RIP     100  1           D   192.168.3.1     GigabitEthernet
0/0/2
```

R3

```
[Huawei dis 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

      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
    192.168.1.0/24  RIP     100  2           D   192.168.3.254   GigabitEthernet
0/0/1
    192.168.2.0/24  RIP     100  1           D   192.168.3.254   GigabitEthernet
0/0/1
    192.168.3.0/24  Direct  0    0           D   192.168.3.1     GigabitEthernet
0/0/1
    192.168.3.1/32  Direct  0    0           D   127.0.0.1       GigabitEthernet
0/0/1
    192.168.4.0/24  RIP     100  1           D   192.168.3.254   GigabitEthernet
0/0/1
    192.168.5.0/24  Direct  0    0           D   192.168.5.1     Ethernet0/0/1
    192.168.5.1/32  Direct  0    0           D   127.0.0.1       Ethernet0/0/1
```

Part D.
OSPF – Open Shortest Path First

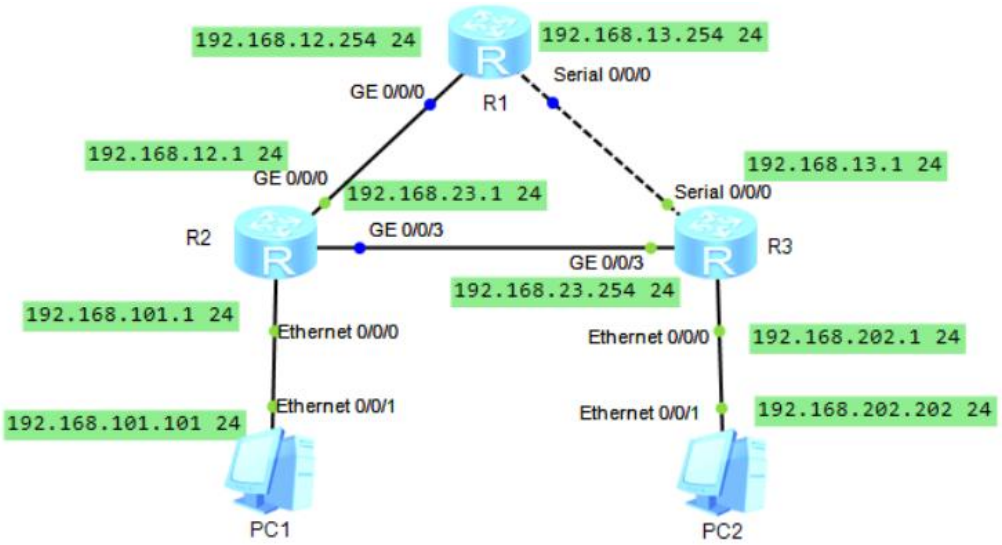
- A link-state routing protocol
- OSPF is classified as an Interior Gateway Protocol (IGP)
- Each router maintains a database describing the Autonomous System's topology

https://www.rfc-editor.org/rfc/rfc2328.txt

OSPF(1)

Configuration on eNSP

- step1 : start OSPF configuration
  - command: **ospf** <process number>
- step2: specify the index of area
  - command: **area** <area index>
- step3: add the network info which is connect directly by the Router
  - command: **network** <network ID> <wildcast mask>
  - wildcast mask：the result of performing bitwise inversion on a 32-bit subnet mask.
    - e.g. the subnet mask is: 255.255.255.0, the the wildcast mask is 0.0.0.255



R1

```
[Huawei]ospf 1
[Huawei-ospf-1]area 0
[Huawei-ospf-1-area-0.0.0.0]network 192.168.12.0 0.0.0.255
[Huawei-ospf-1-area-0.0.0.0]network 192.168.13.0 0.0.0.255
[Huawei-ospf-1-area-0.0.0.0]q
[Huawei-ospf-1]q
[Huawei]
```

R2

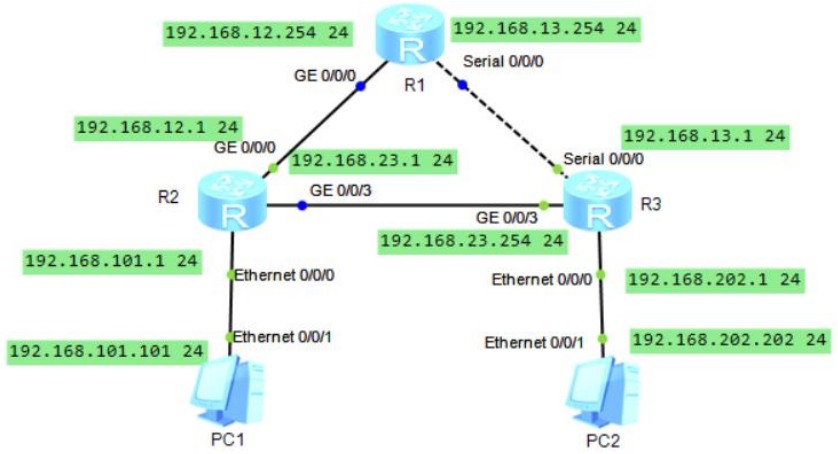
```
[Huawei]ospf 1
[Huawei-ospf-1]area 0
[Huawei-ospf-1-area-0.0.0.0]network 192.168.101.0 0.0.0.255
[Huawei-ospf-1-area-0.0.0.0]network 192.168.12.0 0.0.0.255
[Huawei-ospf-1-area-0.0.0.0]network 192.168.23.0 0.0.0.255
[Huawei-ospf-1-area-0.0.0.0]q
[Huawei-ospf-1]
```

R3

```
[Huawei]ospf 1
[Huawei-ospf-1]area 0
[Huawei-ospf-1-area-0.0.0.0]network 192.168.13.0 0.0.0.255
[Huawei-ospf-1-area-0.0.0.0]network 192.168.23.0 0.0.0.255
[Huawei-ospf-1-area-0.0.0.0]network 192.168.202.0 0.0.0.255
[Huawei-ospf-1-area-0.0.0.0]q
[Huawei-ospf-1]q
[Huawei]
```

OSPF(2)

After the configuration on OSPF is done, using command "**display ospf peer**" to view information about the router's neighbors



R1

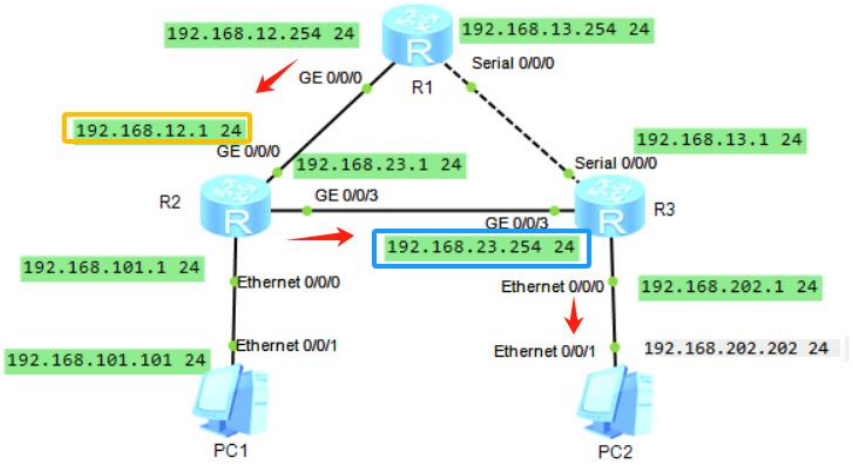
```
[Huawei]dis ospf peer

       OSPF Process 1 with Router ID 192.168.12.254
             Neighbors

 Area 0.0.0.0 interface 192.168.12.254(GigabitEthernet0/0/0)'s neighbors
 Router ID: 192.168.101.1     Address: 192.168.12.1
   State: Full  Mode:Nbr is  Master  Priority: 1
   DR: 192.168.12.1  BDR: 192.168.12.254  MTU: 0
   Dead timer due in 29  sec
   Retrans timer interval: 5
   Neighbor is up for 00:17:48
   Authentication Sequence: [ 0 ]

             Neighbors

 Area 0.0.0.0 interface 192.168.13.254(Serial0/0/0)'s neighbors
 Router ID: 192.168.202.1     Address: 192.168.13.1
   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 00:15:21
   Authentication Sequence: [ 0 ]
```

OSPF(3)

Initiate a “tracert” test from R1 to PC2, tracking the transmission path of the test packets

Q. Why R1 choose R2(192.168.12.1) other than R3(192.168.13.1) as the next hop ?

It seems that from R1 to PC2, passing directly through R3 is the least cost option?



R1

```
[Huawei]tracert 192.168.202.202

 traceroute to  192.168.202.202(192.168.202.202
), max hops: 30 ,packet length: 40,press CTRL_C to break

 1 192.168.12.1 50 ms  50 ms  40 ms

 2 192.168.23.254 60 ms  70 ms  60 ms

 3 192.168.202.202 90 ms  80 ms  100 ms
[Huawei]
```

R1

```
[Huawei]dis ip routing-table
Route Flags: R - relay, D - download to fib
------------------------------------------------------------------------------
Routing Tables: Public
         Destinations : 10        Routes : 10

Destination/Mask    Proto   Pre  Cost      Flags NextHop         Interface

        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
    192.168.12.0/24   Direct  0    0           D   192.168.12.254  GigabitEthernet
0/0/0
  192.168.12.254/32   Direct  0    0           D   127.0.0.1       GigabitEthernet
0/0/0
    192.168.13.0/24   Direct  0    0           D   192.168.13.254  Serial0/0/0
    192.168.13.1/32   Direct  0    0           D   192.168.13.1    Serial0/0/0
  192.168.13.254/32   Direct  0    0           D   127.0.0.1       Serial0/0/0
    192.168.23.0/24   OSPF    10   2           D   192.168.12.1    GigabitEthernet
0/0/0
    192.168.101.0/24  OSPF    10   2           D   192.168.12.1    GigabitEthernet
0/0/0
    192.168.202.0/24  OSPF    10   3           D   192.168.12.1    GigabitEthernet
0/0/0
```

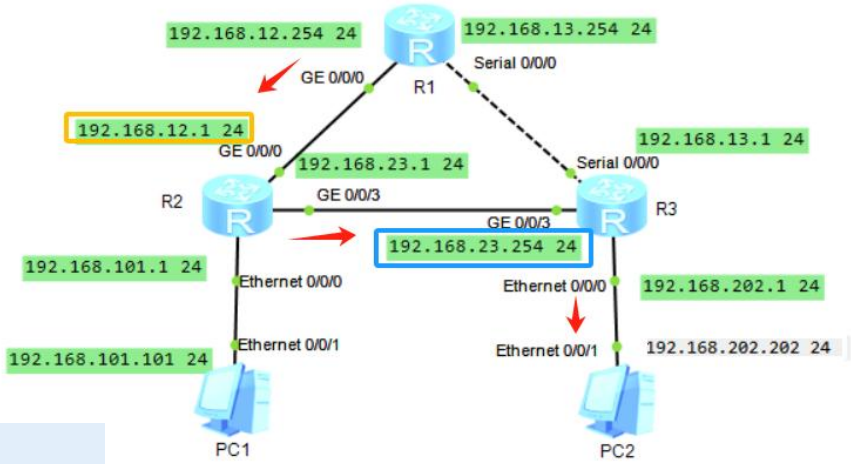
OSPF(4)

Q. How to calculate the “cost” in OSPF ?

link cost

R1->R3->PC2 : 1562 + 1 = 1563

R1->R2->R3->PC2 : 1+1+1 = 3



R1

```
[Huawei]dis ospf routing

      OSPF Process 1 with Router ID 192.168.12.254
            Routing Tables

 Routing for Network
 Destination        Cost  Type       NextHop         AdvRouter       Area
 192.168.12.0/24    1     Transit    192.168.12.254  192.168.12.254  0.0.0.0
 192.168.13.0/24    1562  Stub       192.168.13.254  192.168.12.254  0.0.0.0
 192.168.23.0/24    2     Transit    192.168.12.1    192.168.101.1   0.0.0.0
 192.168.101.0/24   2     Stub       192.168.12.1    192.168.101.1   0.0.0.0
 192.168.202.0/24   3     Stub       192.168.12.1    192.168.202.1   0.0.0.0

 Total Nets: 5
 Intra Area: 5  Inter Area: 0  ASE: 0  NSSA: 0

[Huawei]
```

The route with lowest link cost is the final choice for the Router, so R1->R2->R3->PC2 is the final choice.

R1

```
[Huawei]dis ip routing-table
Route Flags: R - relay, D - download to fib
------------------------------------------------------------------------------
Routing Tables: Public
         Destinations : 10        Routes : 10

Destination/Mask    Proto   Pre  Cost      Flags NextHop         Interface

        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
   192.168.12.0/24    Direct  0    0           D   192.168.12.254  GigabitEthernet
0/0/0
 192.168.12.254/32    Direct  0    0           D   127.0.0.1       GigabitEthernet
0/0/0
   192.168.13.0/24    Direct  0    0           D   192.168.13.254  Serial0/0/0
   192.168.13.1/32    Direct  0    0           D   192.168.13.1    Serial0/0/0
 192.168.13.254/32    Direct  0    0           D   127.0.0.1       Serial0/0/0
   192.168.23.0/24    OSPF    10   2           D   192.168.12.1    GigabitEthernet
0/0/0
  192.168.101.0/24    OSPF    10   2           D   192.168.12.1    GigabitEthernet
0/0/0
  192.168.202.0/24    OSPF    10   3           D   192.168.12.1    GigabitEthernet
0/0/0
```

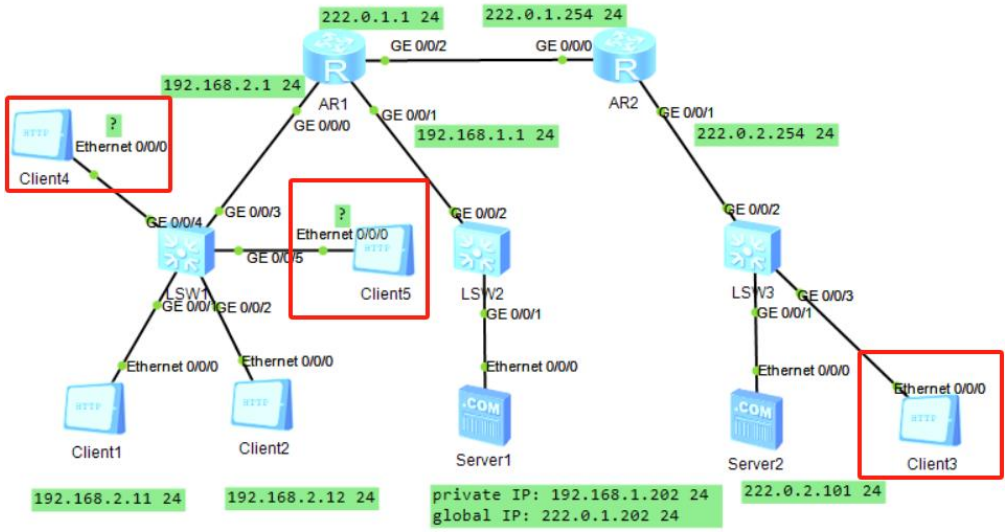
Practice 12.1

Build the following network topology, complete the configuration, achieve the following functions

① Client 1, Client2, Client4 and Client5 are configured with private address while share the same global address 222.0.1.101, clients could access the http server Server2.

- NOTE: The ACL rules related to the NAT/NAPT MUST be : rule 5 permit source 192.168.2.11 0.0.0.15

② Server1 is configurated with private address 192.168.1.202 /24 , the external clients access the server through the server's global address 222.0.1.202/24.



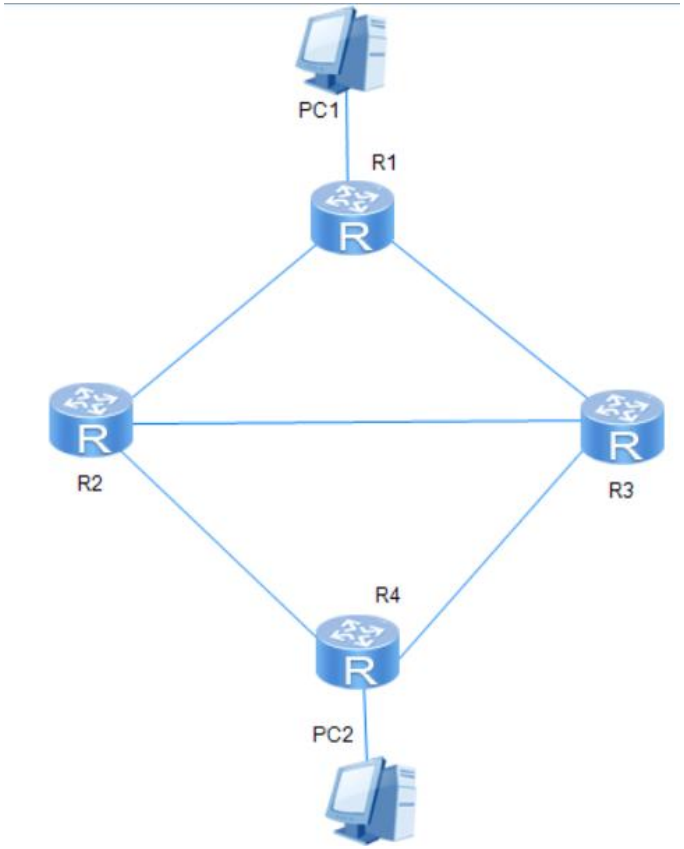
tips:
nat address-group <group id> <x.x.x.x > <x.x.x.x>

acl <acl id>

rule <rule id> permit source <x.x.x.x> <x.x.x.x>

nat outband <acl id> address-group <group id> [no pat]

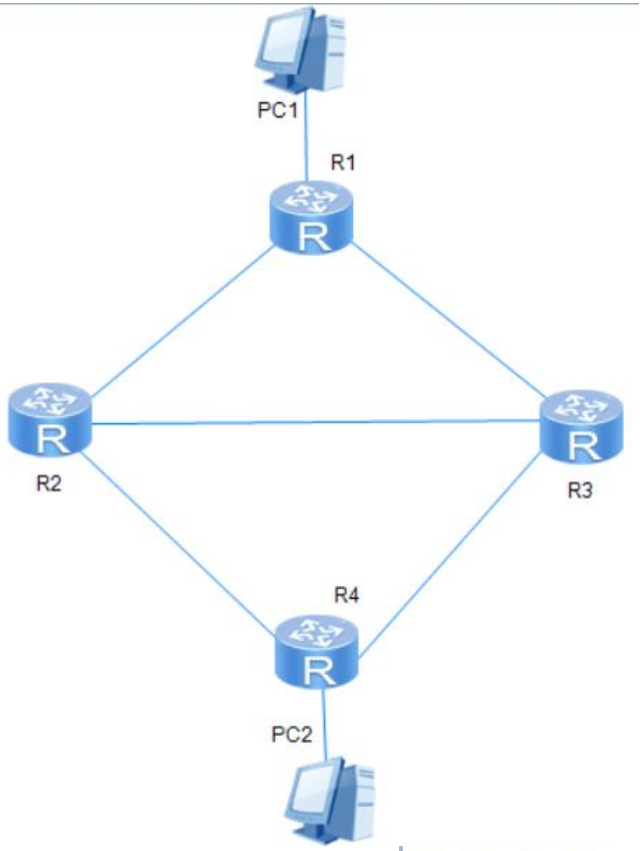
Practice 12.2(1)



Build the network

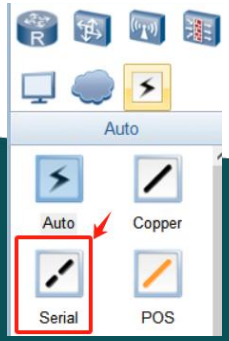
- Do the configuration on PCs and the interfaces of Routers
  - place notes near the interfaces to displace its IPv4 address.
- Enable and configure RIP protocol on routers
  - make all the nodes(including PCs and Routers) reachable in the network.
  - list the route-table on each routers in the network
  - using “ping” on PC1 to check if PC2 is reachable, while ICMP request packet leave from PC1, what's its routing path? is it the shortest path (here shortest path means minimum hops) between two nodes?
- **Tips**: use *“undo rip id”* on router to disable RIP protocol

Practice 12.2(2)



Build the network

- Do the configuration on PCs and the interfaces of Routers
  - place notes near the interfaces to displace its IPv4 address.
- Enable and configure OSPF protocol on routers
  - make all the nodes(including PCs and Routers) reachable in the network.
  - list the route-table on each routers.
  - using “ping” on PC1 to check if PC2 is reachable, while ICMP request packet leave from PC1, what's its routing path? if the routing path is not “R1->R2->R3->R4”, try to make it.
- List the differences between RIP and OSPF protocol(at least 3 aspects) , using this practice to improve it.
- Tips, while using the serial interface of the router, “Serial” of “Connections” is suggested to connect the serial interface.



SUSTech
Southern University
of Science and Technology