Cabrillo College

CISCO SYSTEMS
NETWORKING ACADEMY

Ch. 2 IP Addressing
CCNP - Advanced Routing

Rick Graziani, Instructor
(Modified presentation originally created by Mark McGregor at Los Medanos College)

Feb 5, 2002

1

IPv4 Address Classes

	1st octet	2nd octet	3rd octet	4th octet
Class A	**Network**	**Host**	**Host**	**Host**
Class B	**Network**	**Network**	**Host**	**Host**
Class C	**Network**	**Network**	**Network**	**Host**

2

Class A addresses

First octet is between 0 - 127

Network	**Host**	**Host**	**Host**
	8 bits	**8 bits**	**8 bits**

Number between 0 - 127

With 24 bits available for hosts, there a 2^{24} possible addresses. That's 16,777,216 nodes!

- There are 126 class A addresses.
  - 0 and 127 have special meaning and are not used.
- Only large organizations such as the military, government agencies, universities, and large corporations have class A addresses.
- Cable Modem ISPs have 24.0.0.0
- Pacbell DSL users have 63.0.0.0
- Class A addresses account for 2,147,483,648 of the possible IPv4 addresses.
- That's 50 % of the total unicast address space!

3

Class B addresses

First octet is between 128 - 191

Network	**Network**	**Host**	**Host**
		8 bits	**8 bits**

Number between 128 - 191

With 16 bits available for hosts, there a 2^{16} possible addresses. That's 65,536 nodes!

- There are 16,384 (2^{14}) class B networks.
- Class B addresses represent 25% of the total IPv4 unicast address space.
- Class B addresses are assigned to large organizations including corporations (such as Cisco, government agencies, and school districts).

4

Class C addresses

First octet is between 192 - 223

Network	Network	Network	Host

8 bits

Number between 192 - 223

With 8 bits available for hosts, there a 2^8 possible addresses. That's 256 nodes!

- There are 2,097,152 possible class C networks.
- Class C addresses represent 12.5% of the total IPv4 unicast address space.

5

IP address shortage

- In the early days of the Internet, IP addresses were allocated to organizations based on request rather than actual need.
- No medium size - Hosts:
  - Class A: 16 million
  - Class B: 65,536
  - Class C: 256

Subnet Mask

- The solution to the IP address shortage was *thought* to be the subnet mask.
- Formalized in 1985 (RFC 950), the subnet mask breaks a single class A, B or C network in to smaller pieces**.**

6

Subnet Example

Given the Class B address 190.52.0.0

Class B	Network	Network	Host	Host

Using subnets...

Network	Network	Subnet	Host

Internet **routers still "see" this net as 190.52.0.0**

190.52.2.2
190.52.3.2

But *internal* routers think all these addresses are on different networks, called subnetworks

7

Subnetting

Network	Network	Subnet	Host

Using the 3rd octet, 190.52.0.0 was divided into:

190.52.1.0	190.52.2.0	190.52.3.0	190.52.4.0
190.52.5.0	190.52.6.0	190.52.7.0	190.52.8.0
190.52.9.0	190.52.10.0	190.52.11.0	190.52.12.0
190.52.13.0	190.52.14.0	190.52.15.0	190.52.16.0
190.52.17.0	190.52.18.0	190.52.19.0	and so on ...

8

Need a Subnet Review?

- If you need a Review of Subnets, please review the following links on my web site:
  - Subnet Review (PowerPoint)
  - Subnets Explained (Word Doc)

9

Subnetting

Let's look at a class-C address and a 27-bit mask.

200.1.1.0/24 Class-C address block	200.1.1.0/27
	200.1.1.32/27
	200.1.1.64/27
	200.1.1.96/27
	200.1.1.128/27
	200.1.1.160/27
	200.1.1.192/27
	200.1.1.224/27

10

Subnet	First Host	Last Host	Broadcast
200.1.1.0/27	Can't use 000 and 111 (who told you that!?)		
00000000	00000001	00011110	00011111
200.1.1.32/27			
00100000	00100001	00111110	00111111
200.1.1.64/27			
01000000	01000001	01011110	01011111
200.1.1.96/27			
01100000	01100001	01111110	01111111
200.1.1.128/27			
10000000	10000001	10011110	10011111
200.1.1.160/27			
10100000	10100001	10111110	10111111
200.1.1.192/27			
11000000	11000001	11011110	11011111
200.1.1.224/27	Can't use 000 and 111 (who told you that!?)		
11100000	11100001	11111110	11111111

Enabling the use of subnet zero, "0"

- The Cisco IOS allows you to use subnet 0.
- On pre-IOS 12.x releases, this feature is **not** enabled by default.

```
Router(config)#ip subnet-zero
```

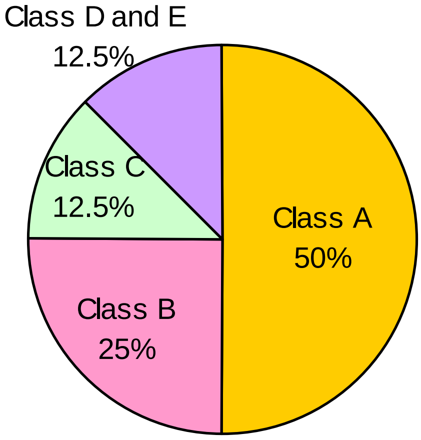
- On IOS 12.x releases and later, this feature is enabled by default.
- This command also enables process of routing updates containing information about zero subnets.

Enabling the use of the all 1's subnet

- Although this Cisco IOS will allow you to configure addresses in the all-ones subnet, this is highly discouraged.
- As a general rule, do not use the all-ones subnet.

Problems with IPv4 Addressing

- Address Depletion
- Internet Routing Table Explosion



13

Long-term solution: IPv6

- IP v6, or IPng (IP – the Next Generation) uses a 128-bit address space, yielding

  340,282,366,920,938,463,463,374,607,431,768,211,456

  possible addresses.
- IPv6 has been slow to arrive
  - IPv4 revitalized by new features, making IPv6 a luxury, and not a desperately needed fix
  - IPv6 requires new software; IT staffs must be retrained
- IPv6 will most likely coexist with IPv4 for years to come.
  - Some experts believe IPv4 will remain for more than 10 years.

14

IPv6 Address format - FYI

- *Unicast*: An identifier for a single interface.
- *Anycast*: An identifier for a set of interfaces (typically belonging to different nodes). A packet sent to an anycast address is delivered to the "nearest," or first, interface in the anycast group.
  - A mechanism for addressing multiple interfaces, usually on different nodes, with the same IP address Traffic destined to the address gets routed to the nearest node." Jeff Doyle

  Searchnetworking.com
  - In Internet Protocol Version 6 (IPv6), anycast is communication between a single sender and the nearest of several receivers in a group. The term exists in contradistinction to multicast, communication between a single sender and multiple receivers, and unicast, communication between a single sender and a single receiver in a network.
  - Anycasting is designed to let one host initiate the efficient updating of router tables for a group of hosts. IPv6 can determine which gateway host is closest and sends the packets to that host as though it were a unicast communication. In turn, that host can anycast to another host in the group until all routing tables are updated.
- *Multicast*: An identifier for a set of interfaces (typically belonging to different nodes). A packet sent to a multicast address is delivered to all interfaces in the multicast group.

IPv6 address format - FYI

- IPv6 can be written as 32 hex digits, with colons separating the values of the eight 16-bit pieces of the address:

  FEDC:BA98:7654:3210:FEDC:BA98:7654:3210

- This example address shows that leading zeros in each 16-bit value can be omitted:

  1080:0:0:0:8:800:200C:417A

- Because IPv6 addresses, especially in the early implementation phase, may contain consecutive 16-bit values of zero, one such string of 0s per address can be omitted and replaced by a double colon, so this:

  1080:0:0:0:8:800:200C:417A

  can be shortened to become this:

  1080::8:800:200C:417A

- The IPv6 loopback address

  0:0:0:0:0:0:0:1

  This can be written as this:

  ::1

IPv6 address format

IPv6 address has three levels of hierarchy
(See book/on-line for more information.)

Number of Bits

3	13	8	24	16	64
FP	TLA ID	Res	NLA ID	SLA ID	Interface ID
Public Topology				Site Topology	Interface Identifier

17

IPv4 Solutions to address crisis

- Even as work progressed on the next generation of IP addressing, network engineers continued to develop IPv4 so that it could handle the address crunch.

IPv4 Addressing enhancements

- CIDR
- VLSM
- Private Addressing (RFC 1918)
- NAT/PAT

18

CIDR - Classless Interdomain Routing

- Note: We will visit CIDR again when we discuss BGP and how it help reduced the Internet routing table explosion.
  - We will also see of the difficulties CIDR presents to anyone wishing to connect to multiple service providers or wishing more portability with their address space.
- Classless Interdomain Routing
  - "classless IP"
  - pronounced "cider"
- To CIDR-compliant routers, **address class is meaningless**.
  - The network portion of the address is determine by network prefix (/8, /19, etc.)
  - The network address is **NOT** determined by the first octet (first two bits).
  - 200.10.0.0/16 or 15.10.160.0/19

19

CIDR and Route Summarization

- First deployed in 1994, CIDR dramatically improves IPv4's scalability and efficiency by providing the following:
  - The replacement of classful addressing with a more flexible and less wasteful classes scheme (VLSM)
  - Enhanced route aggregation (summarization), also known as supernetting
- CIDR allows routers to aggregate, or *summarize*, routing information and thus shrink the size of their routing tables.
  - Just one address and mask combination can represent the routes to multiple networks.
  - Used by IGP routers within an AS and EGP routers between AS.
- We will see how this benefits the Internet (EGP routers), i.e. Network Service Providers, Regional Service Providers, and ISPs later when we address BGP.

20

Without CIDR, a router must maintain individual routing table entries for these class B networks.

Network Number	First Octet	Second Octet	Third Octet	Fourth Octet
172.24.0.0 /16	10101100	00011000	00000000	00000000
172.25.0.0 /16	10101100	00011001	00000000	00000000
172.26.0.0 /16	10101100	00011010	00000000	00000000
172.27.0.0 /16	10101100	00011011	00000000	00000000
172.28.0.0 /16	10101100	00011100	00000000	00000000
172.29.0.0 /16	10101100	00011101	00000000	00000000
172.30.0.0 /16	10101100	00011110	00000000	00000000
172.31.0.0 /16	10101100	00011111	00000000	00000000

With CIDR, a router can summarize these routes into eight networks by using a 13-bit prefix: **172.24.0.0 /13**

Network Number	First Octet	Second Octet (This one too...)	Third Octet	Fourth Octet
172.24.0.0 /16	10101100	00011000	00000000	00000000
172.25.0.0 /16	10101100	00011001	00000000	00000000
172.26.0.0 /16	10101100	00011010	00000000	00000000
172.27.0.0 /16	10101100	00011011	00000000	00000000
172.28.0.0 /16	10101100	00011100	00000000	00000000
172.29.0.0 /16	10101100	00011101	00000000	00000000
172.30.0.0 /16	10101100	00011110	00000000	00000000
172.31.0.0 /16	10101100	00011111	00000000	00000000

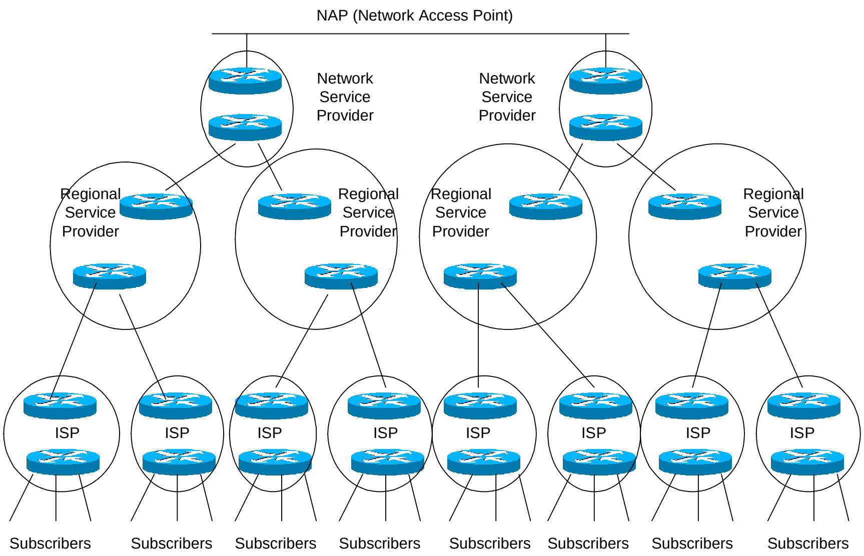
Route summarization

- By using a prefix address to summarizes routes, administrators can keep routing table entries manageable, which means the following
  - More efficient routing
  - A reduced number of CPU cycles when recalculating a routing table, or when sorting through the routing table entries to find a match
  - Reduced router memory requirements
- Route summarization is also known as:
  - Route aggregation
  - Supernetting
- Supernetting is essentially the inverse of subnetting.

Supernetting and address allocation

- CIDR moves the responsibility of allocation addresses away from a centralized authority (InterNIC).
- Instead, ISPs can be assigned blocks of address space, which they can then parcel out to customers.

ISP/NAP Hierarchy - “The Internet: Still hierarchical after all these years.” Jeff Doyle *(Tries to be anyways!)*



CIDR and the Internet

Regional Service Providers

- Local ISPs connect to Regional Service Providers such as Sprint, PacBell,

Network Service Providers

- Regional Service Providers connect to Network Service Providers such as:
  - MCI/WorldCom (UUNET)
  - SprintNet
  - Cable & Wireless
  - Concentric Network
  - PSINet

Network Access Points (NAPs)

- Network Service Providers inerconnect via NAPs
- A NAP is a LAN or Switch, typically Ethernet, FDDI or ATM across which different providers exchange routes and data traffic.
- Some well-know NAPs in the US
  - New York NAP, New Jersey, Sprint
  - San Francisco NAP, SF Ca, Pac Bell
  - MAE-West, San Jose, Ca, MCI/WorldCom
  - MAE-Chicago, Chicago, Ill, MCI/WorldCom

24

Supernetting Example

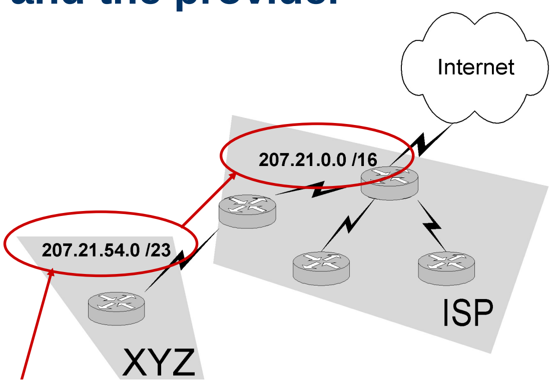
- Company XYZ needs to address 400 hosts.
- Its ISP gives them two contiguous Class C addresses:
  - 207.21.54.0/24
  - 207.21.55.0/24
- Company XYZ can use a prefix of **207.21.54.0 /23** to supernet these two contiguous networks. (Yielding 510 hosts)
  - **207.21.54.0 /23**
    - 207.21.54.0/24
    - 207.21.55.0/24

Network Number	First Octet	Second Octet	Third Octet	Fourth Octet
207.21.54.0	11001111	00010101	00110110	00000000
207.21.55.0	11001111	00010101	00110111	00000000

23 bits in common

25

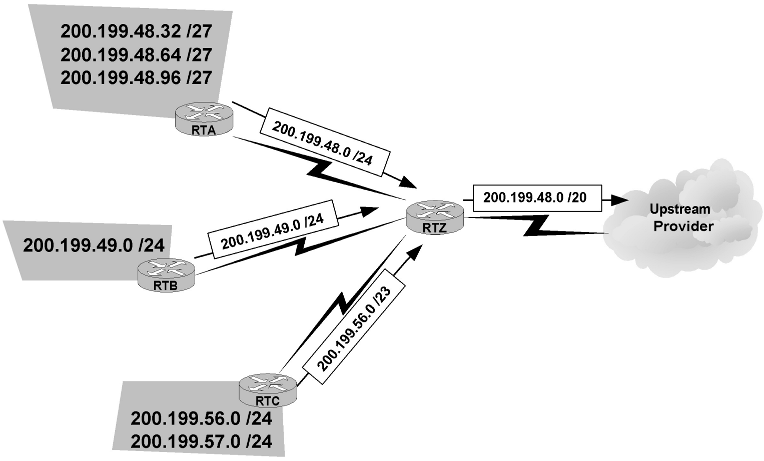
CIDR and the provider



- With the ISP acting as the addressing authority for a CIDR block of addresses, the ISP's customer networks, which include XYZ, can be advertised among Internet routers as a single supernet.

Network Number	First Octet	Second Octet	Third Octet	Fourth Octet
207.21.54.0	11001111	00010101	00110110	00000000
207.21.55.0	11001111	00010101	00110111	00000000

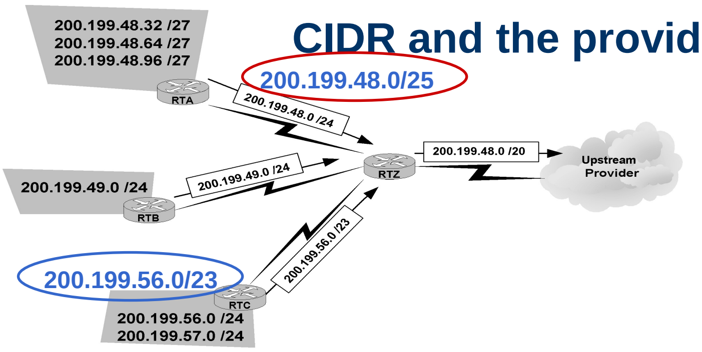
CIDR and the provider



Another example of route aggregation.

27

CIDR and the provider



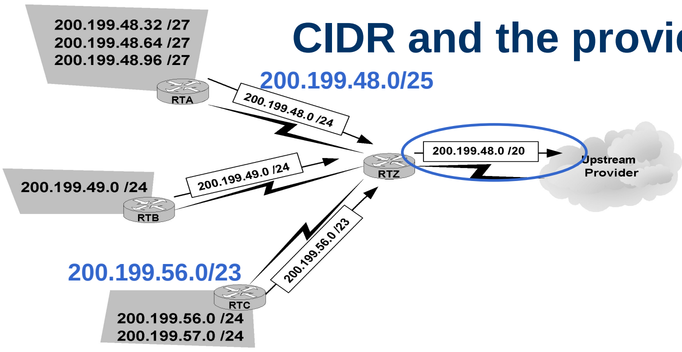
Even Better:

200.199.48.32/27 11001000 11000111 00110000 0 0100000
200.199.48.64/27 11001000 11000111 00110000 0 1000000
200.199.48.96/27 11001000 11000111 00110000 0 1100000
200.199.48.0/25 11001000 11000111 00110000 0 0000000

(As long as there are no other routes elsewhere that fall within this range.)

200.199.56.0/24 11001000 11000111 0011100 0 00000000
200.199.57.0/24 11001000 11000111 0011100 1 00000000
200.199.56.0/23 11001000 11000111 0011100 0 00000000

CIDR and the provider



200.199.48.0/25	11001000 11000111 0011 0000 00000000
200.199.49.0/25	11001000 11000111 0011 0001 00000000
200.199.56.0/23	11001000 11000111 0011 1000 00000000
200.199.48.0/20	11001000 11000111 0011 0000 00000000

- **20** bits in common

CIDR restrictions

- Dynamic routing protocols must send prefix and mask information in their routing updates.
- In other words, CIDR requires **classless routing protocols**.
- Note: There are other CIDR restrictions that we will discuss during the chapter on BGP.

Classful vs Classless Protocols

Classful Routing Protocols	Classless Routing Protocols
RIP version 1	RIP version 2
IGRP	EIGRP
EGP	OSPF
BGP3	IS-IS
	BGP4

30

Classful vs Classless Routing Behavior

- This is **different** the classful and classless routing protocols.
- By default, classless routing behavior is enabled on the router. (IOS 12.0)
- When classless routing is in effect, if a router receives packets destined for a subnet of a network that has no network default route, the router forwards the packet to the best supernet route.

For more information, view my PowerPoint presentation on:

- **The Routing Table, Structure, Lookup Process and the ip classless command**
- ***We will look at this presentation next!***

31

VLSM

Variable-length subnet masking

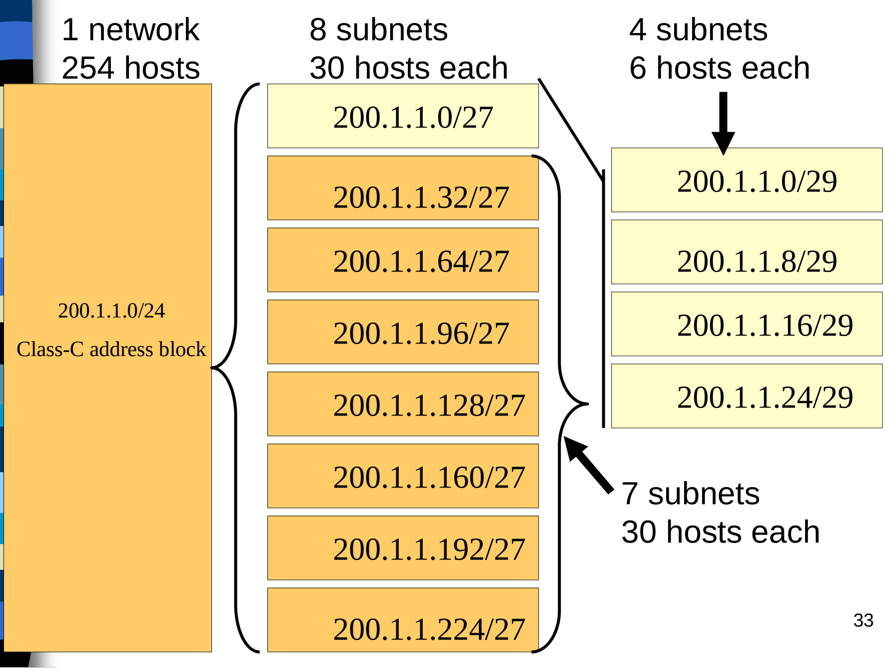
- VLSM allows an organization to use more than one subnet mask within the same network address space.
  - "subnetting a subnet"

Here is a simple example: 10.0.0.0/8

- First we subnet **10.0.0.0/8** into 256 /16 subnets
  - 10.0.0.0/16, 10.1.0.0/16, 10.2.0.0/16, 10.3.0.0/16, thru 10.255.0.0/16
- Next we take one of the /16 subnets, **10.1.0.0/16** and subnet it further into 256 /24 subnets.
  - 10.1.0.0/24, **10.1.1.0/24**, 10.1.2.0/24, 10.1.3.0/24, thru 10.1.255.0/24

	1st octet	2nd octet	3rd octet	4th octet
10.0.0.0/8	10	Host	Host	Host
10.1.0.0/16	10	1	Host	Host
10.1.1.0/24	10	1	1	Host

Another Example



33

VLSM

Network	First Octet	Second Octet	Third Octet	Fourth Octet
200.1.1.0/27	11001000	00000001	00000001	00000000
200.1.1.32/27	11001000	00000001	00000001	00100000
200.1.1.64/27	11001000	00000001	00000001	01000000
200.1.1.96/27	11001000	00000001	00000001	01100000
200.1.1.128/27	11001000	00000001	00000001	10000000
200.1.1.160/27	11001000	00000001	00000001	10100000
200.1.1.192/27	11001000	00000001	00000001	11000000
200.1.1.224/27	11001000	00000001	00000001	11100000

200.1.1.0/24 subnetted into 8 /27 subnets

34

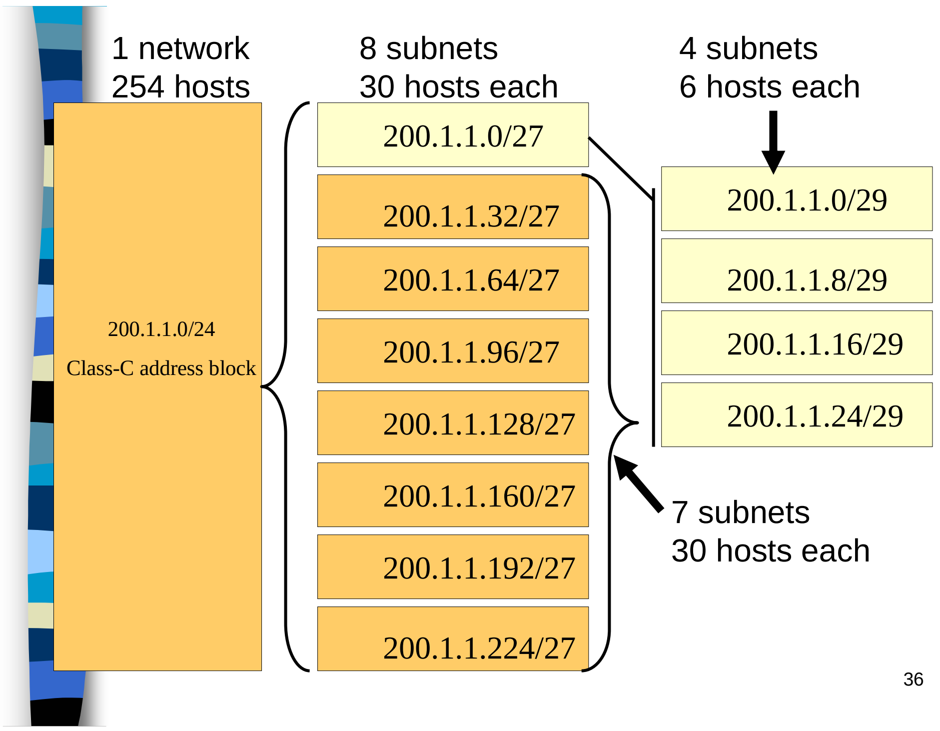
Network	First Octet	Second Octet	Third Octet	Fourth Octet
200.1.1.0/27	11001000	00000001	00000001	00000000
200.1.1.32/27	11001000	00000001	00000001	00100000
200.1.1.64/27	11001000	00000001	00000001	01000000
200.1.1.96/27	11001000	00000001	00000001	01100000
200.1.1.128/27	11001000	00000001	00000001	10000000
200.1.1.160/27	11001000	00000001	00000001	10100000
200.1.1.192/27	11001000	00000001	00000001	11000000
200.1.1.224/27	11001000	00000001	00000001	11100000

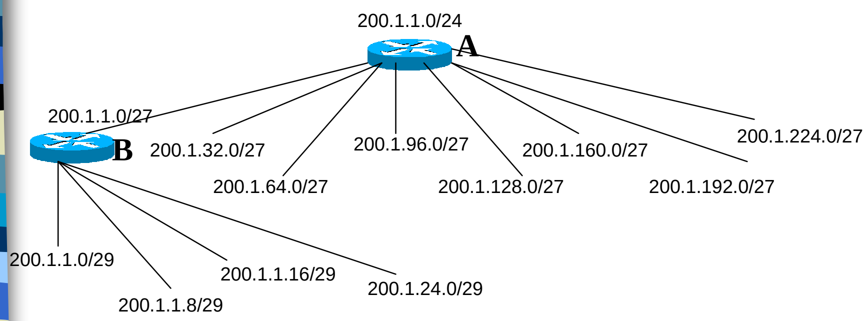
Network	First Octet	Second Octet	Third Octet	Fourth Octet
200.1.1.0/27	11001000	00000001	00000001	00000000

Network	First Octet	Second Octet	Third Octet	Fourth Octet
200.1.1.0/29	11001000	00000001	00000001	00000000
200.1.1.8/29	11001000	00000001	00000001	00001000
200.1.1.16/29	11001000	00000001	00000001	00010000
200.1.1.24/29	11001000	00000001	00000001	00011000

Subnet the network: 200.1.1.0/24 subnetted into 8 /27 subnets

Subnet the first subnet again: 200.1.1.0/27 subnetted into 4 /29 subnets

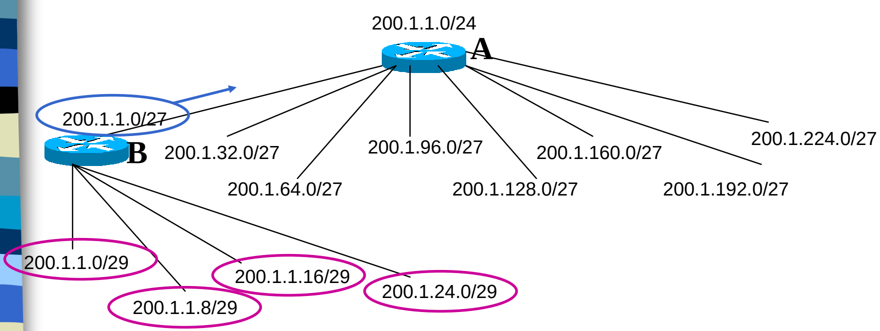




VLSM

- 200.1.1.0/24 subnetted into eight /27 subnets
- One /27 subnet, subnetted into four /29 subnets
- Resulting in seven /27 subnets and four /29 subnets
- Routing protocol must be "classless" (OSPF, EIGRP)

37



VLSM

- Four /29 subnets can be aggregated (summarized) into one /27, **but** does not have to.
- /29 addresses could be spread out elsewhere, however this would not allow them to be summarized, creating larger routing tables, etc.
- RouterA could see /27 and /29 addresses, classless.

38

VLSM using a 30-bit mask

Subnet 0	207.21.24.0 /27
Subnet 1	207.21.24.32 /27
Subnet 2	207.21.24.64 /27
Subnet 3	207.21.24.96 /27
Subnet 4	207.21.24.128 /27
Subnet 5	207.21.24.160 /27
Subnet 6	207.21.24.192 /27
Subnet 7	207.21.24.224 /27

Sub-subnet 0	207.21.24.192 /30
Sub-subnet 1	207.21.24.196 /30
Sub-subnet 2	207.21.24.200 /30
Sub-subnet 3	207.21.24.204 /30
Sub-subnet 4	207.21.24.208 /30
Sub-subnet 5	207.21.24.212 /30
Sub-subnet 6	207.21.24.216 /30
Sub-subnet 7	207.21.24.220 /30

Convert these to binary!

39

VLSM using a 30-bit mask

Subnet 0	207.21.24.0 /27
Subnet 1	207.21.24.32 /27
Subnet 2	207.21.24.64 /27
Subnet 3	207.21.24.96 /27
Subnet 4	207.21.24.128 /27
Subnet 5	207.21.24.160 /27
Subnet 6	207.21.24.192 /27
Subnet 7	207.21.24.224 /27

Sub-subnet 0	207.21.24.192 /30
Sub-subnet 1	207.21.24.196 /30
Sub-subnet 2	207.21.24.200 /30
Sub-subnet 3	207.21.24.204 /30
Sub-subnet 4	207.21.24.208 /30
Sub-subnet 5	207.21.24.212 /30
Sub-subnet 6	207.21.24.216 /30
Sub-subnet 7	207.21.24.220 /30

207.21.24.192/27	11001111 00010101 00011000 11000000
207.21.24.192/30	11001111 00010101 00011000 11000000
207.21.24.196/30	11001111 00010101 00011000 11000100
207.21.24.200/30	11001111 00010101 00011000 11001000
207.21.24.204/30	11001111 00010101 00011000 11001100
207.21.24.208/30	11001111 00010101 00011000 11010000
207.21.24.212/30	11001111 00010101 00011000 11010100
207.21.24.216/30	11001111 00010101 00011000 11011000
207.21.24.220/30	11001111 00010101 00011000 11011100

VLSM using a 30-bit mask

Subnet 0	207.21.24.0 /27
Subnet 1	207.21.24.32 /27
Subnet 2	207.21.24.64 /27
Subnet 3	207.21.24.96 /27
Subnet 4	207.21.24.128 /27
Subnet 5	207.21.24.160 /27
Subnet 6	207.21.24.192 /27
Subnet 7	207.21.24.224 /27

Sub-subnet 0	207.21.24.192 /30
Sub-subnet 1	207.21.24.196 /30
Sub-subnet 2	207.21.24.200 /30
Sub-subnet 3	207.21.24.204 /30
Sub-subnet 4	207.21.24.208 /30
Sub-subnet 5	207.21.24.212 /30
Sub-subnet 6	207.21.24.216 /30
Sub-subnet 7	207.21.24.220 /30

207.21.24.192/27 11001111 00010101 00011000 11000000

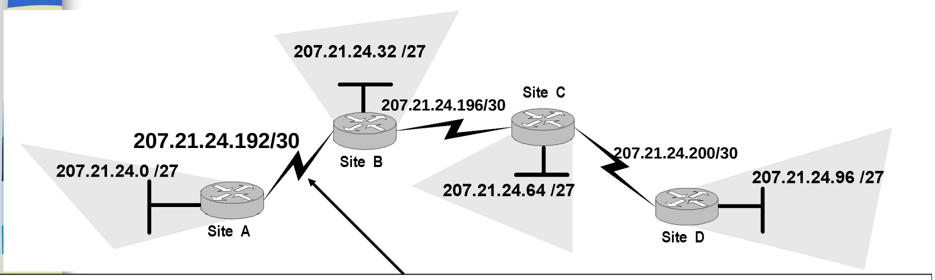
		Net	1st	Lst	BCast
207.21.24.192/30	11001111 00010101 00011000 11000000		01	10	11
207.21.24.196/30	11001111 00010101 00011000 11000100		01	10	11
207.21.24.200/30	11001111 00010101 00011000 11001000		01	10	11
207.21.24.204/30	11001111 00010101 00011000 11001100		01	10	11
207.21.24.208/30	11001111 00010101 00011000 11010000		01	10	11
207.21.24.212/30	11001111 00010101 00011000 11010100		01	10	11
207.21.24.216/30	11001111 00010101 00011000 11011000		01	10	11
207.21.24.220/30	11001111 00010101 00011000 11011100		01	10	11

What good is a 30-bit mask?

Subnet 0	207.21.24.0 /27
Subnet 1	207.21.24.32 /27
Subnet 2	207.21.24.64 /27
Subnet 3	207.21.24.96 /27
Subnet 4	207.21.24.128 /27
Subnet 5	207.21.24.160 /27
Subnet 6	207.21.24.192 /27
Subnet 7	207.21.24.224 /27

Sub-subnet 0	207.21.24.192 /30
Sub-subnet 1	207.21.24.196 /30
Sub-subnet 2	207.21.24.200 /30
Sub-subnet 3	207.21.24.204 /30
Sub-subnet 4	207.21.24.208 /30
Sub-subnet 5	207.21.24.212 /30
Sub-subnet 6	207.21.24.216 /30
Sub-subnet 7	207.21.24.220 /30

- Point-to-point WAN links must be addressed.



		Net	1st	Lst	BCast
207.21.24.192/30	11001111 00010101 00011000 11000000		01	10	11

```
RTA(config)#interface e0
RTA(config-if)#ip add 207.21.24.33 255.255.255.224
RTA(config-if)#interface s0
RTA(config-if)#ip add 207.21.24.193 255.255.255.252

RTA#show ip route
Codes: C-connected, S-static, I-IGRP, R-RIP, M-mobile, B-BGP
       D-EIGRP, EX-EIGRP external, O-OSPF, IA-OSPF inter area
       E1-OSPF external type 1, E2-OSPF external type 2, E-EGP
       i-IS-IS, L1-IS-IS level-1, L2-IS-IS level-2,
   *-candidate default

Gateway of last resort is not set
   207.21.24.0 is variably subnetted, 2 subnets, 2 masks

C    207.21.24.32 255.255.255.224 is directly connected, Ethernet0
C    207.21.24.192 255.255.255.252 is directly connected, Serial0
```

- The parent network shows that the networks are variably subnetted.
- With VLSM, the subnet mask is included with the child routes, not the parent.
- See presentation**: Routing Table, Structure, Lookup and the ip classless command**.

43

VLSM restrictions

- In order to use VLSM with a dynamic routing protocol, the protocol must send subnet information in its updates.
- VLSM requires a **classless routing protocol**.
- Note: If there are two different routes to the same network, a router will always choose the most specific match, "**longest bit match**".
  - For more information, view my PowerPoint presentation on:
    - **The Routing Table, Structure, Lookup Process and the ip classless command**
    - ***We will look at this presentation next!***

44

Alternative Point-To-Point Addressing

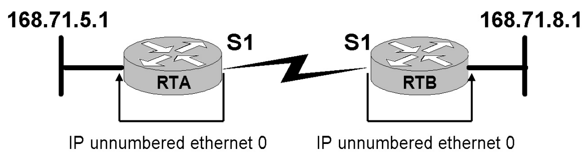
- VLSM is often used to create 2-host networks for point-to-point links.
- Other solutions include:
  - IP unnumbered (RFC 1812)
  - Private addressing (RFC 1918)

IP Unnumbered – RFC 1812

- When a serial interface is configured for IP unnumbered, it borrows the IP address of another interface (usually a LAN interface) and therefore does not need its own address.
- Not only does IP unnumbered avoid wasting addresses on point-to-point WAN links, it can also be used with classful routing protocols.
- If your network runs **RIPv1** or **IGRP**, IP unnumbered *may be the only solution to maximize your addresses*.

IP Unnumbered example

- By using IP unnumbered, serial interfaces can “borrow” an IP address from another interface, including a loopback interface.



Restriction(s):

- The interface is both serial and connected via a point-to-point link
- Curriculum adds these which are not accurate:
  - [The same major network with the same mask is used to address the LAN interfaces that “lend” their IP address on both sides of the WAN link.]

    or
  - Different major networks with no subnetting are used to address the LAN interfaces on both sides of the WAN link.
- Reason: For serial point-to-point, the next-hop address is not used by the Routing Table process, only the exit interface.

IP Unnumbered drawbacks

Using IP unnumbered is not without its drawbacks, which include the following:

- You cannot use **ping** to determine whether the interface is up because the interface has no IP address.
- You cannot boot from a network IOS image over an unnumbered serial interface.
- You cannot support IP security options on an unnumbered interface.

47

Private Addressing

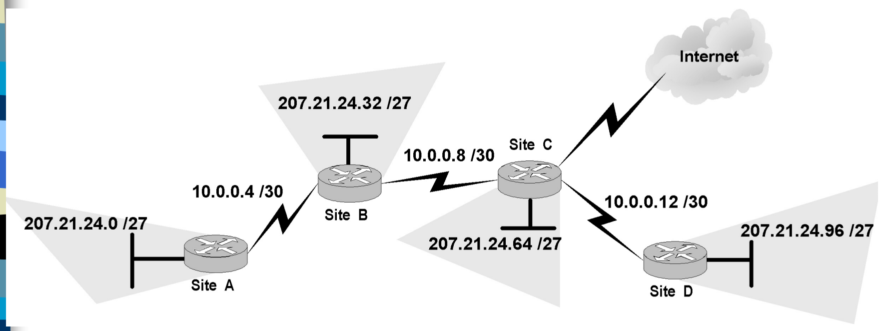
Class	RFC 1918 Internal Address Range	CIDR Prefix
A	10.0.0.0 – 10.255.255.255	10.0.0.0 /8
B	172.16.0.0 – 172.31.255.255	172.16.0.0 /12
C	192.168.0.0 – 192.168.255.255	192.168.0.0 /16

- RFC 1918 specifies reserved ranges of IP addresses to be used for internal networks only.
- These address ranges will not (should not) be routed out on the Internet.
  - ISPs normally filter out these addresses, on both an outgoing and incoming basis to filter out 1918 address space from leaking into other autonomous systems.
- If you are addressing a non-public intranet, a test lab, or a home network, these private addressed can be used instead of globally unique addresses, which must be obtained from a provider or registry at some expense.

48

Private Addresses

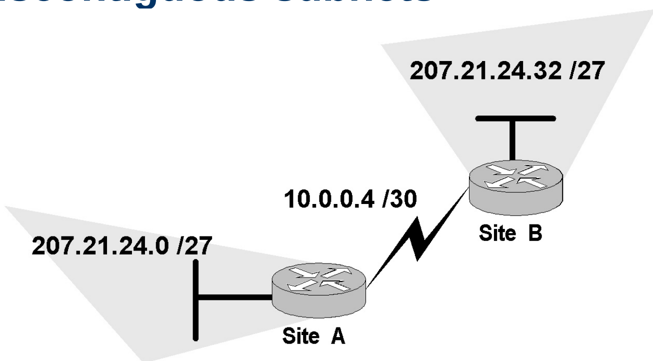
Private address are often used in production networks with Internet connectivity.



Many times, the entire customer network will use private address space, using NAT/PAT to translate between the private and public addresses. (coming)

49

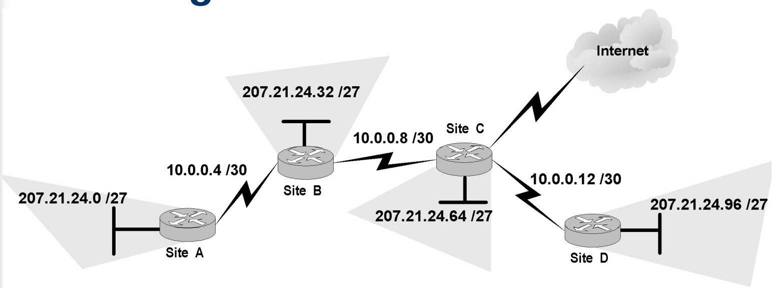
Discontiguous subnets



- Mixing private addresses with globally unique addresses can create **discontiguous subnets**, which are subnets from the same major network that are separated by a completely different major network or subnet.
- **Question**: If a classful routing protocol like RIPv1 or IGRP is being used, what do the routing updates look like between Site A router and Site B router?

50

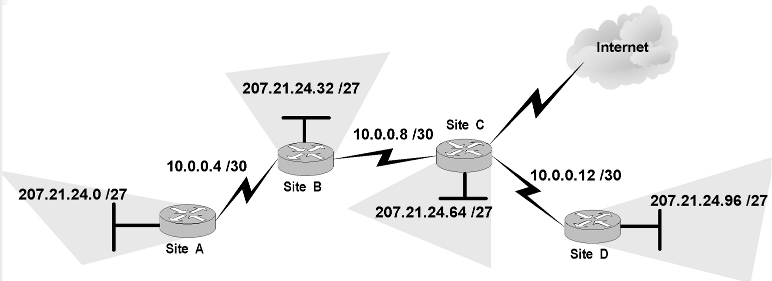
Discontiguous subnets



- Classful routing protocols, notably RIPv1 and IGRP, can't support discontiguous subnets, because the subnet mask is not included in routing updates.
- RIPv1 and IGRP automatically summarize on classful boundaries.
- RtrA, RtrB, RtrC and RtrD are all sending each other the classful address of **207.21.24/24**.
- A classless routing protocol (RIPv2, EIGRP, OSPF) would be needed:
  - to not summarize the classful network address and
  - to include the subnet mask in the routing updates.

51

Discontiguous Subnets



- RIPv2 and EIGRP automatically summarize on classful boundaries. To disable automatic summarization:

```
Router(config-router)#no auto-summary
```

- RtrC now receives 207.21.24.0/27 and 207.21.24.32/27 from RtrB and 207.21.24.96/27 from RtrD

52

Private addresses and NAT

NAT: Network Address Translation

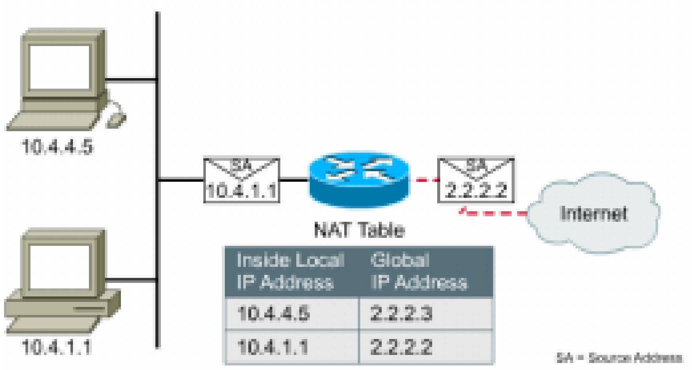
- **NAT**, as defined by RFC 1631, is the process of swapping one address for another in the IP packet header.
- In practice, NAT is used to allow hosts that are privately addressed to access the Internet.

Note: NAT, PAT, TCP load distribution and Easy IP are not part of the Routing exam, but is on the Remote Access exam and covered in the CIS 186 Remote Access class.

- The following slides are FYI and we will discuss only the concepts and not the configurations (CIS 186 Remote Access).

53

NAT



Inside Local IP Address	Global IP Address
10.4.4.5	2.2.2.3
10.4.1.1	2.2.2.2

- One advantage of NAT is that, since not every inside host needs outside access at the same time, you can get away with using a small pool of globally unique addresses to serve a relatively large number of privately addressed hosts.
- Disadvantage of NAT by itself is only a one-to-one mapping.
- This has a limitation ff more hosts need access to the Internet then there are public access addresses.
  - If the private address space is a /8, but the public address is a /24 only 254 hosts can access the Internet at a time.

54

NAT

- Because outside hosts never see the "pre-translated" inside addresses, NAT has the **effect of hiding the inside structure** of a network.
- Although NAT is <u>not a security firewall</u>, it can prevent outsiders from connecting directly to inside hosts, unless a permanent global address mapping exists in the NAT table.
- If you actually wants outside users to access an internally addressed webserver, you can **statically map a global address (2.2.2.3) to an inside address (10.0.0.1).**
  - Static mappings exist in the NAT table until they are removed by an administrator.
  - Internet hosts, and DNS, can use the global address to access the privately addressed webserver.
- Since CIDR places the authority to assign addresses at the ISP level, if you **moved from one ISP to another**, your company may have to completely readdress its systems with the new ISP's CIDR block.
  - Instead of readdressing, NAT can be deployed to temporarily translate the old addresses to new ones, with static mappings in place to keep web and other public services available to the outside

55

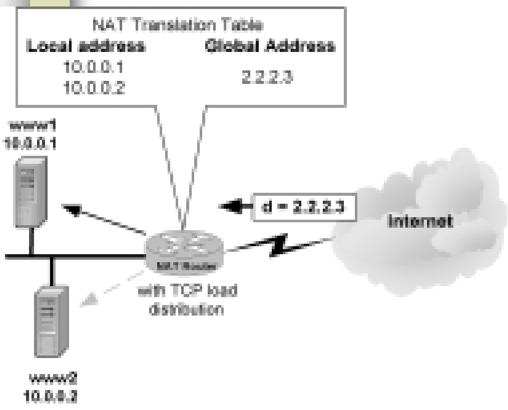
PAT: Address overloading

- The most powerful feature of NAT routers is their ability to use Port Address Translation (**PAT**), which allows multiple inside addresses to map to the same global address.
  - This is sometimes called a "many-to-one" NAT.
  - Literally hundreds of privately address nodes can access the Internet using only one global address.
- The NAT box keeps track of the different conversations by mapping TCP and UDP source port numbers.

Protocol	Inside Local IP Address: Port	Inside Global IP Address: Port
TCP	10.1.1.2:1373	2.2.2.3: **:1111**
TCP	10.1.1.3:1103	2.2.2.3: **:2222**
TCP	10.1.1.3:1743	2.2.2.3: **:3333**

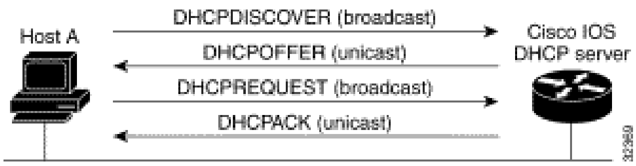
56

TCP Load distribution



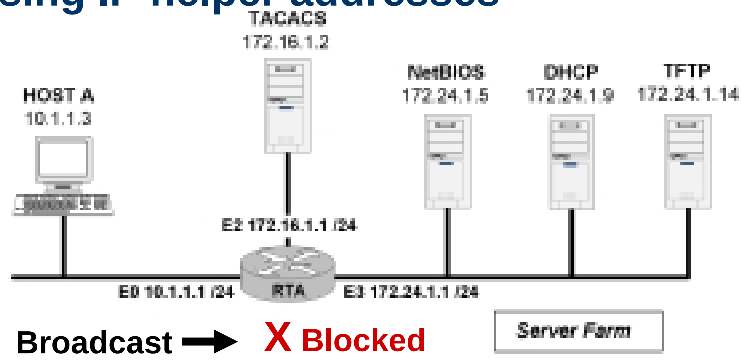
- As an extension to static mapping, Cisco routers support **TCP load distribution**, a powerful NAT feature that allows you to map one global address to multiple inside addresses for the purpose of distributing conversations among multiple (usually mirrored) hosts.

DHCP



- **Dynamic Host Control Protocol**
- Desktop clients are often automatically assigned IP configurations using **DHCP**.
- DHCP servers can also offer other information, such as:
  - DNS server addresses
  - WINS server addresses
  - domain names.
- If a suitable server solution can't be found, a Cisco router can be pressed into duty as a DHCP server.
- The Cisco IOS offers an optional, fully featured DHCP server, which leases configurations for 24 hours by default.

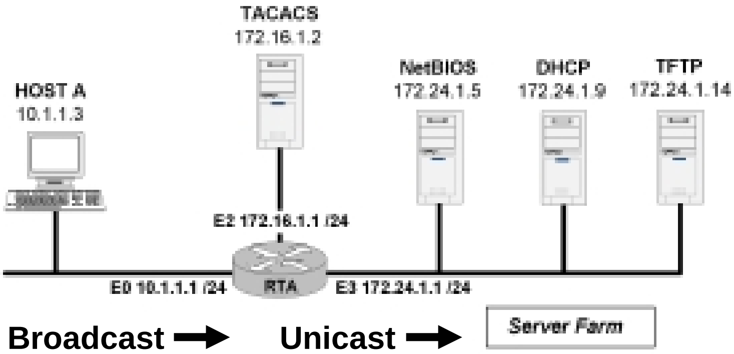
Using IP helper addresses



- DHCP is not the only critical service that uses broadcasts.
  - Cisco routers and other devices may use broadcasts to locate TFTP servers.
  - Some clients may need to broadcast in order to locate a TACACS+ (security) server.
- In a complex, hierarchical network, chances are that not all clients reside on the same subnet as these key servers.

59

Using IP helper addresses




```
RTA(config)#  interface ethernet 0
RTA(config-if)# ip helper-address 172.24.1.9
```

- When possible, administrators use the **ip helper-address** command to relay broadcast requests for these key UDP services.
- By using the helper address feature, a router can be configured to accept a layer 3 broadcast request for a UDP service and then forward it as a unicast to a specific IP address.
  - Alternately, the router can forward these requests as directed broadcasts to a specific network or subnetwork.

60

The 8 default services

UDP Service	UDP Port
Time	37
TACACS	49
DNS	53
BOOTP/DHCP	67
BOOTP/DHCP	68
Netbios Name	137
Netbios Datagram	138
TFTP	69

61

IP helper-addresses & IP forward-protocol

- Q: What if you need to forward requests for a service not on this list?
- A: The Cisco IOS provides the global configuration command, **ip forward-protocol**, to allow an administrator to forward any UDP port in addition to the default eight.

```
RtrA(config)# ip forward-protocol udp 517
```

- Same for removing protocols you do not want to forward.

```
RtrA(config)# no ip forward-protocol udp 69
```

62

Using ip directed broadcast

- To enable the translation of directed broadcast (172.24.1.255) to a layer 2 physical broadcast, use the **ip directed-broadcast** interface configuration command.

```
ip directed-broadcast [access-list-number]
```

- AS for IP directed broadcast, my understanding is that you need to enable this feature if you have several servers on the same network and you are going to have multiple UDP services forwarded to that network.
- For example, you have a NetBIOS server (172.24.1.5), a DHCP server (172.24.1.9), and a TFTP server (172.24.1.14).
- You can either specify both addresses as helper addresses or specify 172.24.1.255 as a helper address on **E0**:

```
RTA(config-if)# ip helper-address 172.24.1.255
```

- If you turn on directed broadcast on **E3**, the latter method will work. (If you don't, it won't.)

```
RTA(config-if)# ip directed-broadcast
```

63

Cabrillo College

CISCO SYSTEMS
NETWORKING ACADEMY

Ch. 2 IP Addressing
CCNP - Advanced Routing
Rick Graziani, Instructor

64