Computer Networks: Network Layer

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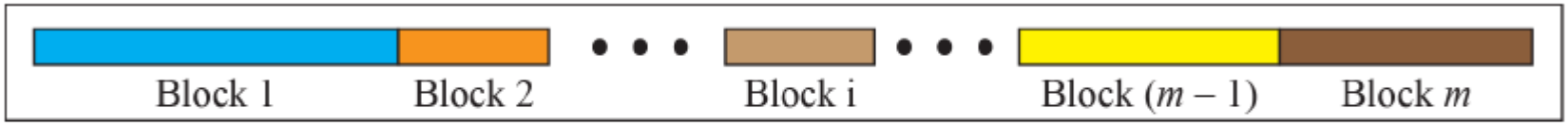
Acknowledgement: Slides and Images adapted from Kurose, and Forouzan (TMH)

Classless IP Address

Variable length Blocks:



Address space

Slash notation (CIDR)

Prefix length

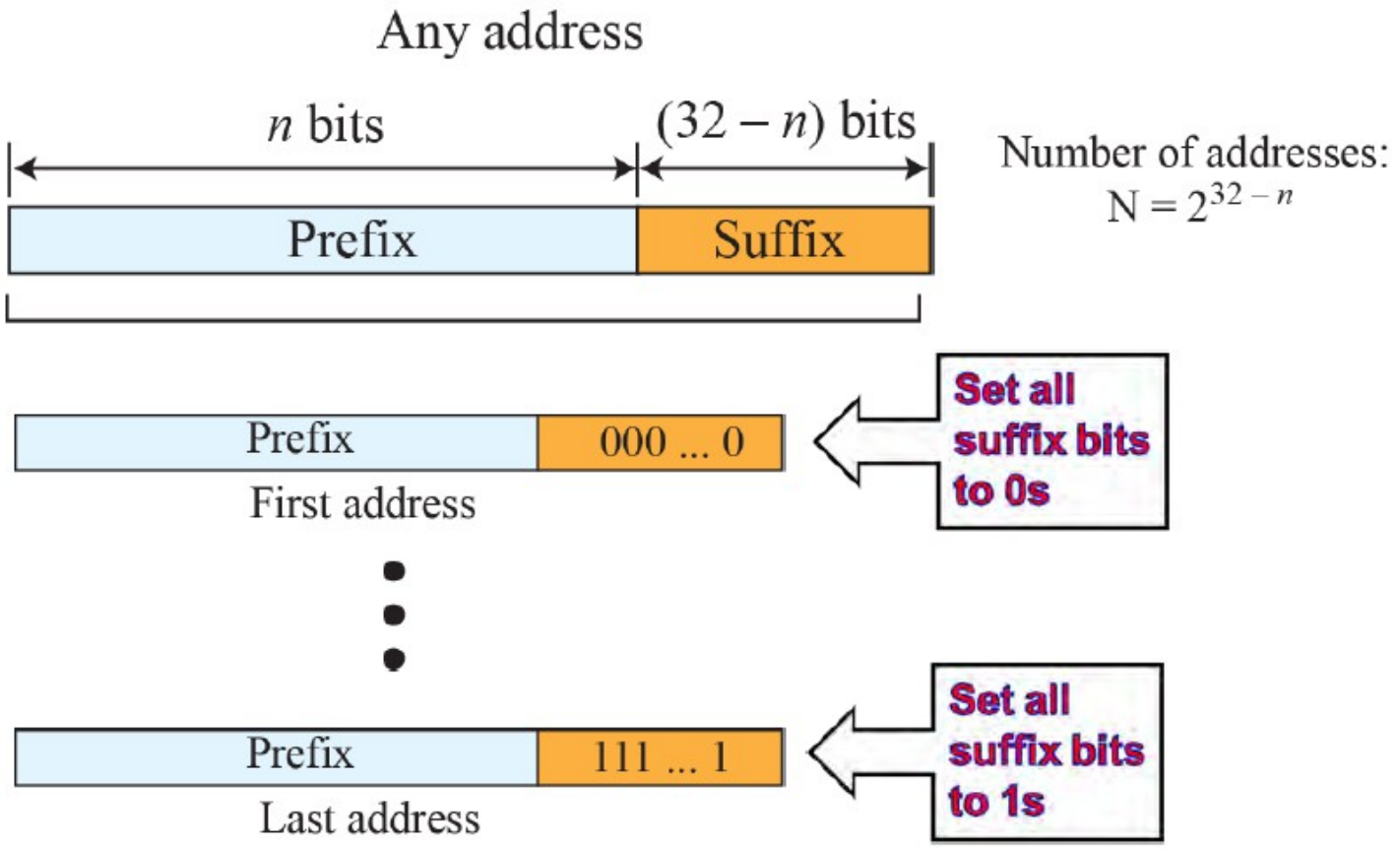
Examples:

12.24.76.8/**8**

23.14.67.92/**12**

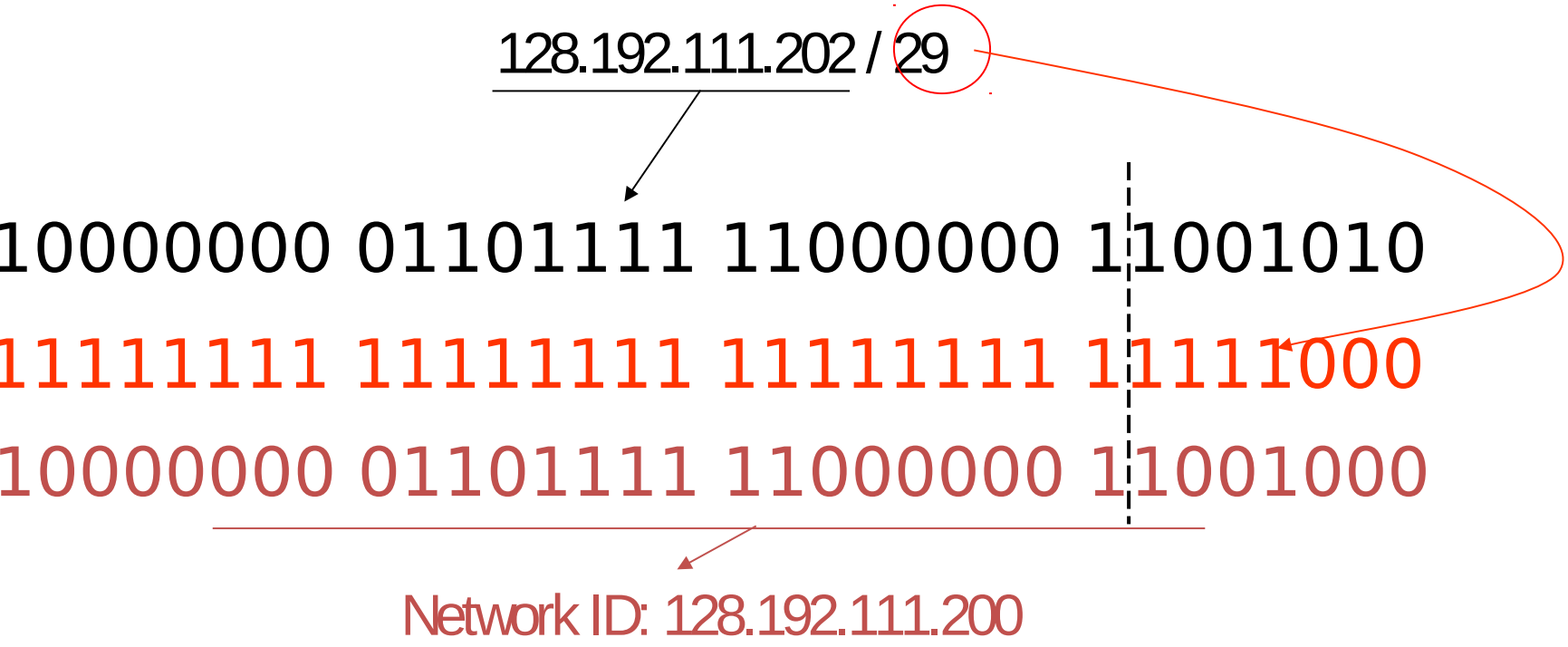
220.8.24.255/**25**

Information Extraction

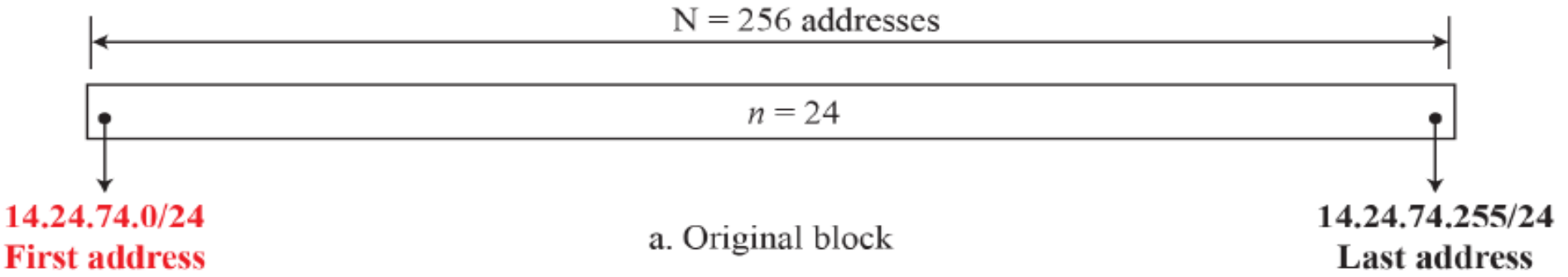


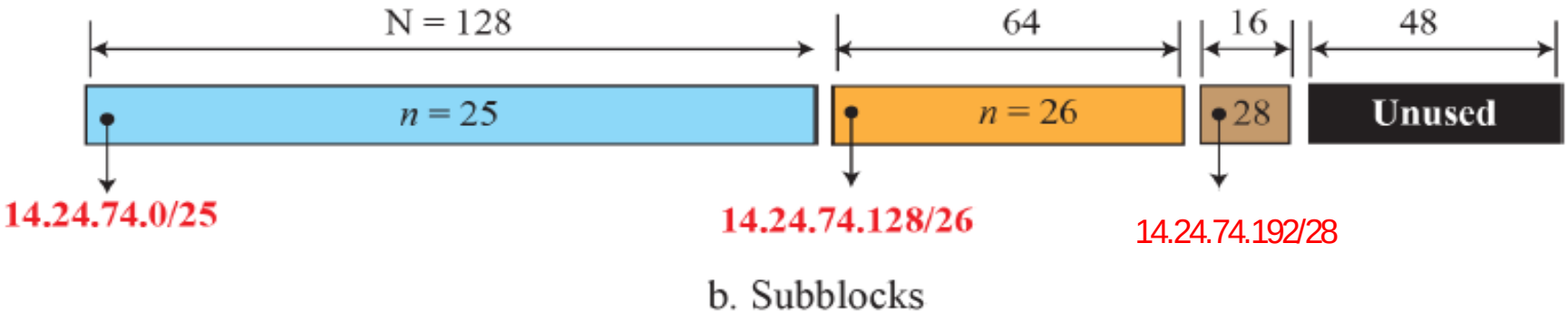
A classless address is given as 167.199.170.82/27. Find First and Last address.

CIDR in Internet Protocol



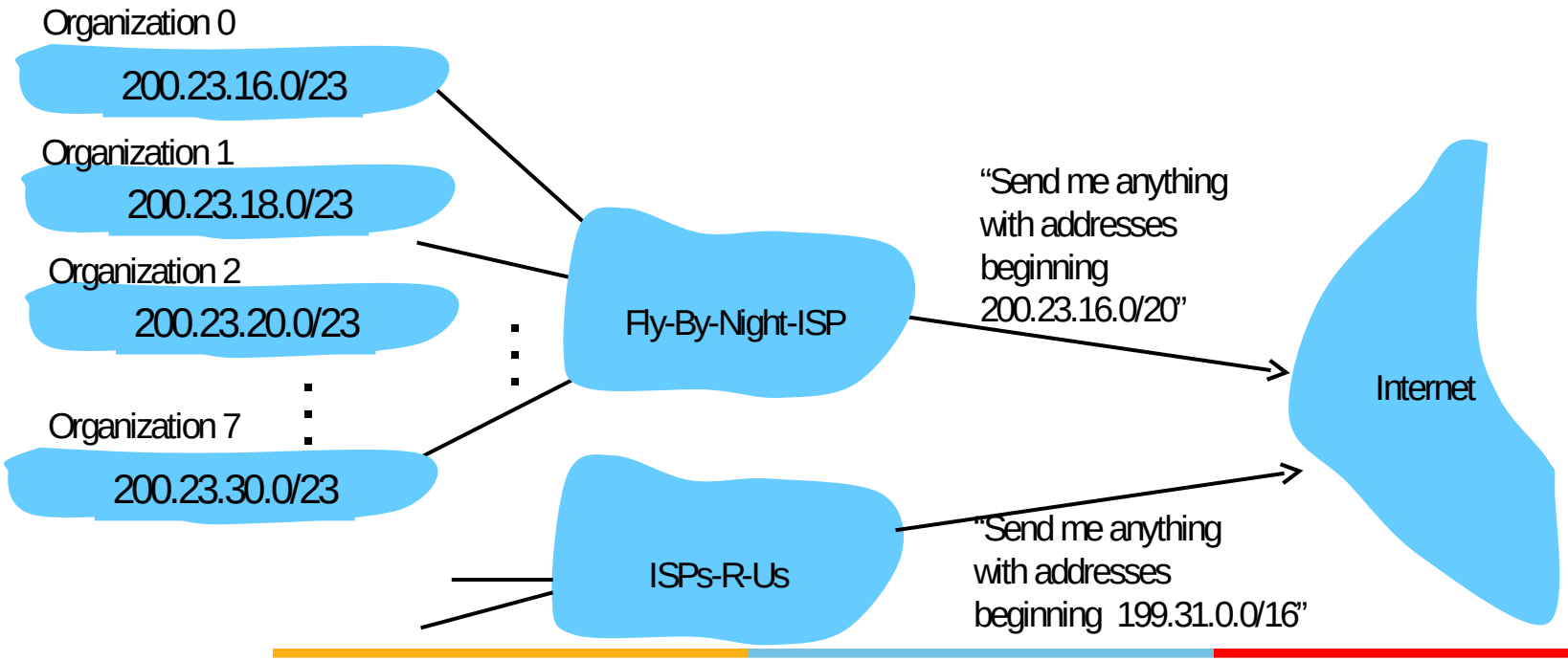
An Example


N = 256 addresses
n = 24
14.24.74.0/24
First address
a. Original block
14.24.74.255/24
Last address

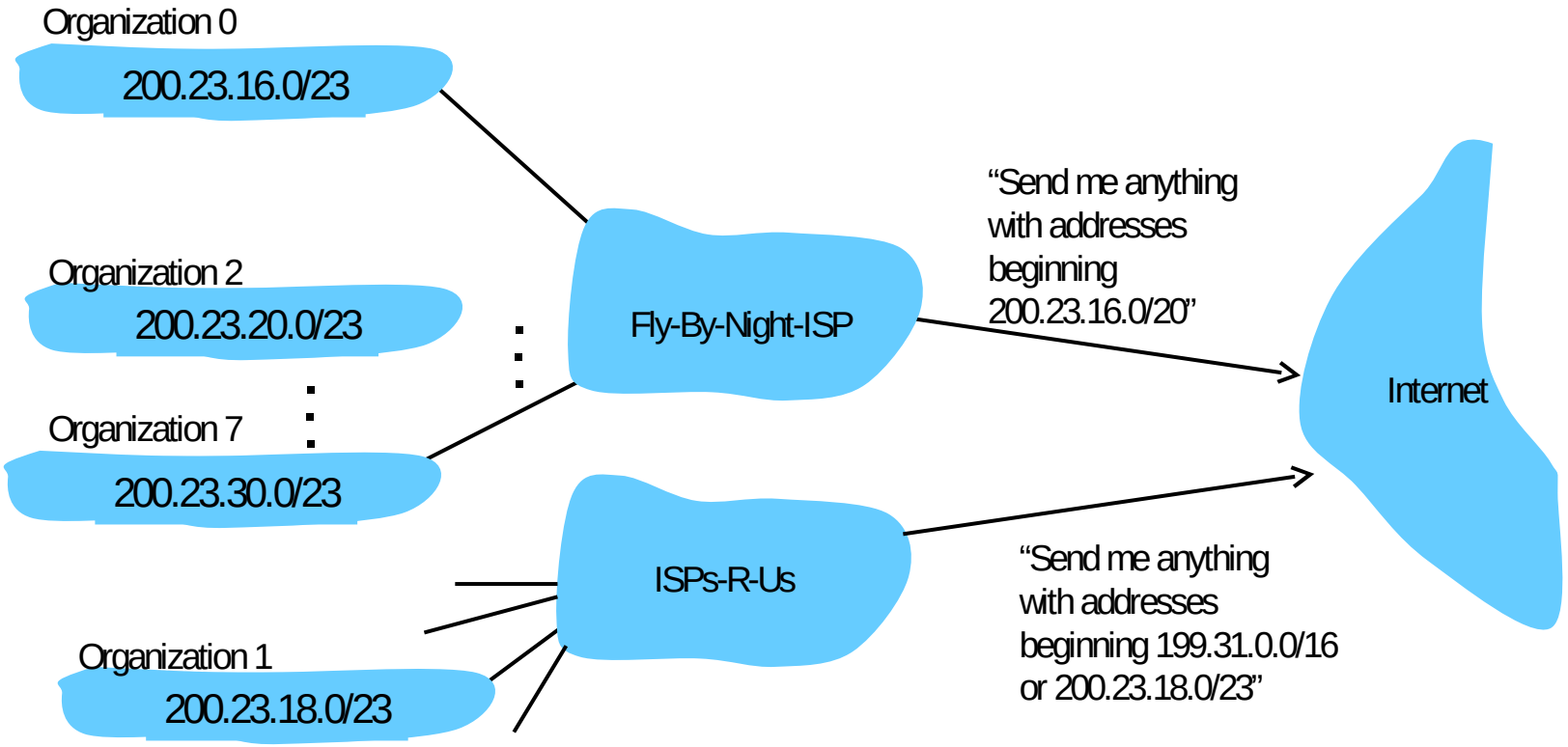

N = 128
64
16
48
n = 25
n = 26
28
Unused
14.24.74.0/25
14.24.74.128/26
14.24.74.192/28
b. Subblocks

Route aggregation in CIDR

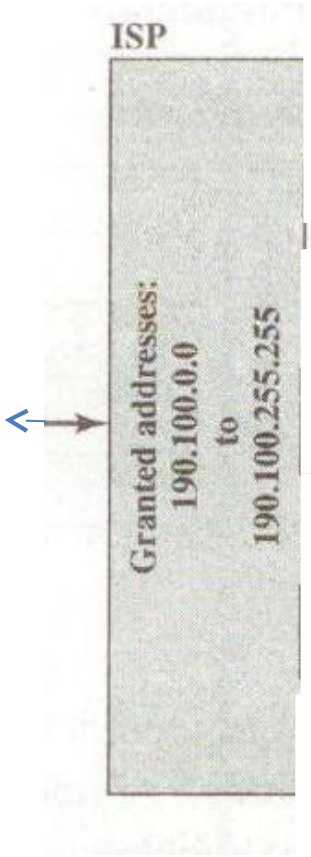
ISP's block	11001000 00010111 00010000	00000000	200.23.16.0/20
Organization 0	11001000 00010111 00010000	00000000	200.23.16.0/23
Organization 1	11001000 00010111 00010010	00000000	200.23.18.0/23
Organization 2	11001000 00010111 00010100	00000000	200.23.20.0/23
...	.....	....	....
Organization 7	11001000 00010111 00011110	00000000	200.23.30.0/23



More specific route



Another Example



64 customers with each 256 addresses

128 customers with each 128 addresses

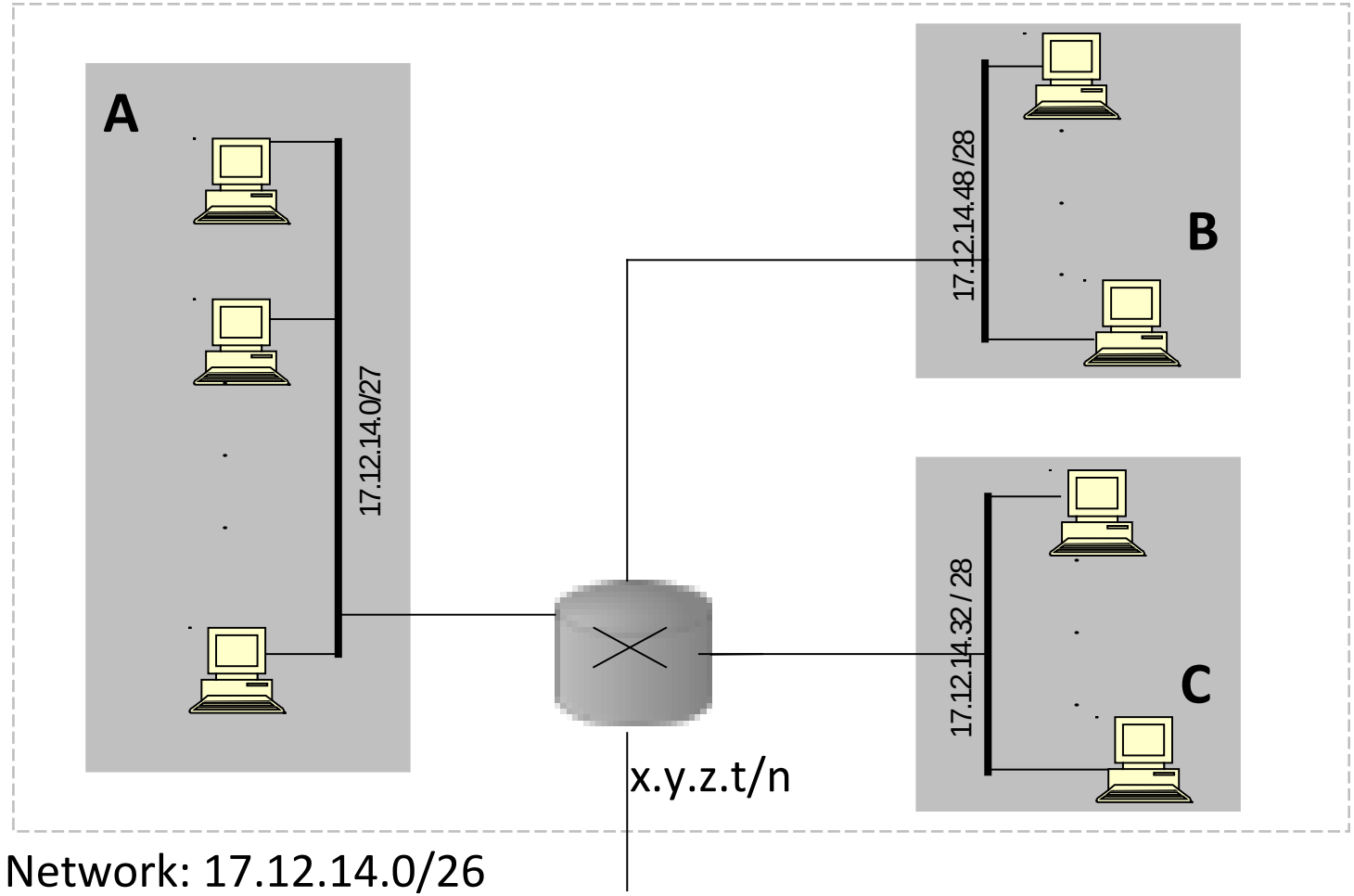
128 customers with each 64 addresses

1st Customer:	*190.100.0.0/24*	*190.100.0.255/24*
2nd Customer:	*190.100.1.0/24*	*190.100.1.255/24*
. . .		
64th Customer:	*190.100.63.0/24*	*190.100.63.255/24*
Total = 64 × 256 = 16,384		

1st Customer:	*190.100.64.0/25*	*190.100.64.127/25*
2nd Customer:	*190.100.64.128/25*	*190.100.64.255/25*
. . .		
128th Customer:	*190.100.127.128/25*	*190.100.127.255/25*
Total = 128 × 128 = 16,384		

1st Customer:	*190.100.128.0/26*	*190.100.128.63/26*
2nd Customer:	*190.100.128.64/26*	*190.100.128.127/26*
. . .		
128th Customer:	*190.100.159.192/26*	*190.100.159.255/26*
Total = 128 × 64 = 8192		

Let us try…

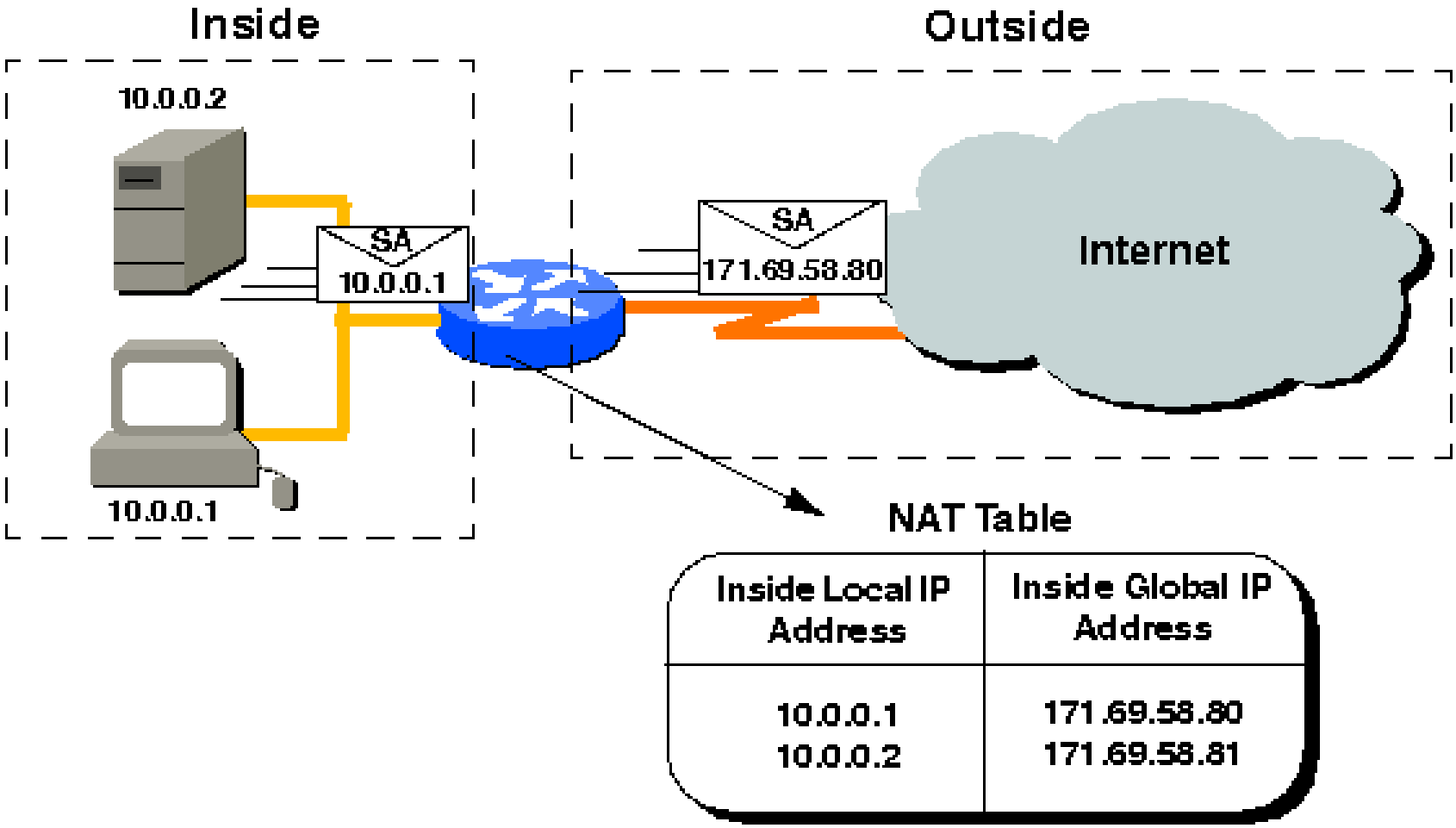

A
17.12.14.0/27
B
17.12.14.48 /28
C
17.12.14.32 / 28
x.y.z.t/n
Network: 17.12.14.0/26

Network Address Translation: Why?

Expand IP address space by deploying private address and translating them into publicly registered addresses.

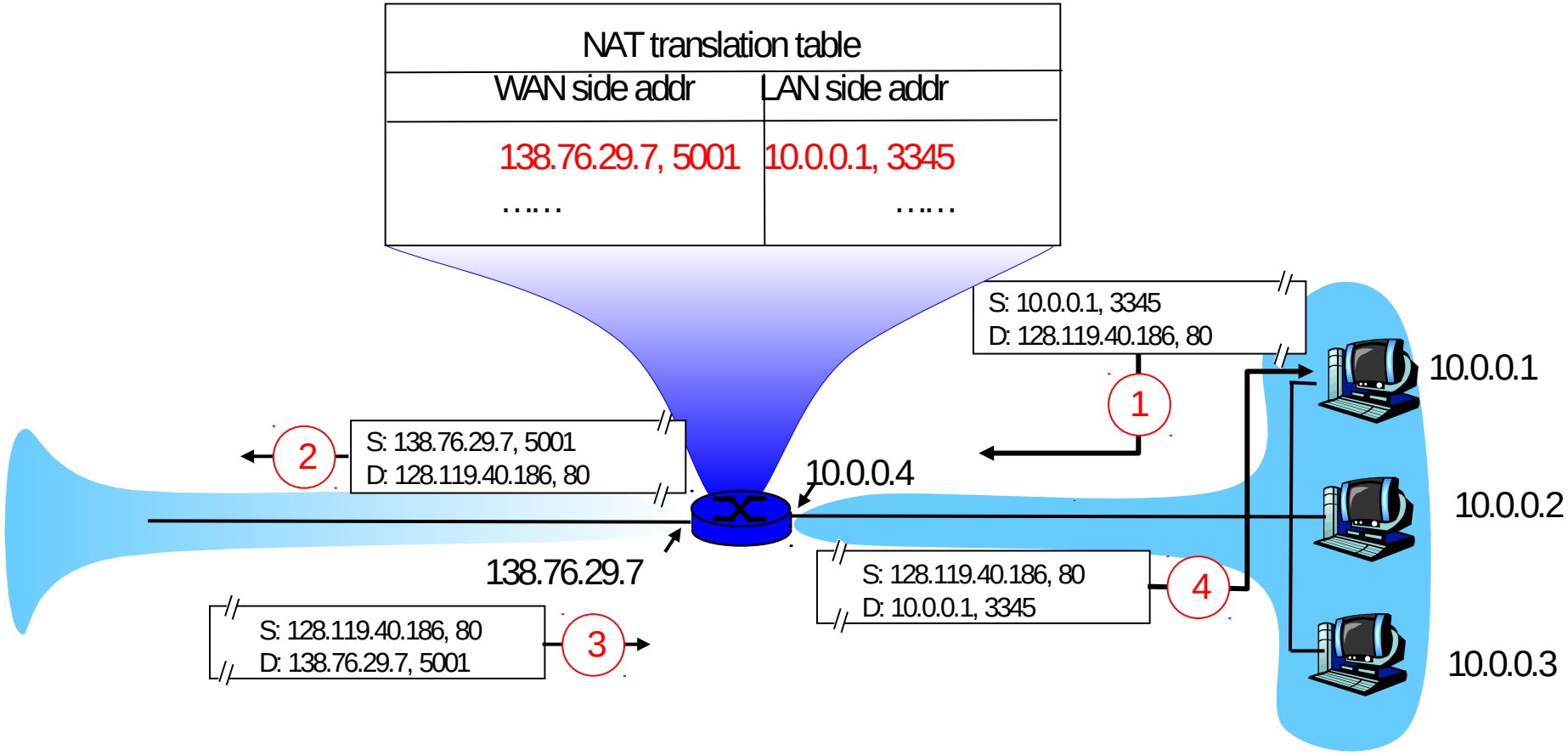
Not every printer / fax machine / IPod / etc. needs to be publicly accessible from the Internet.

NAT Modes

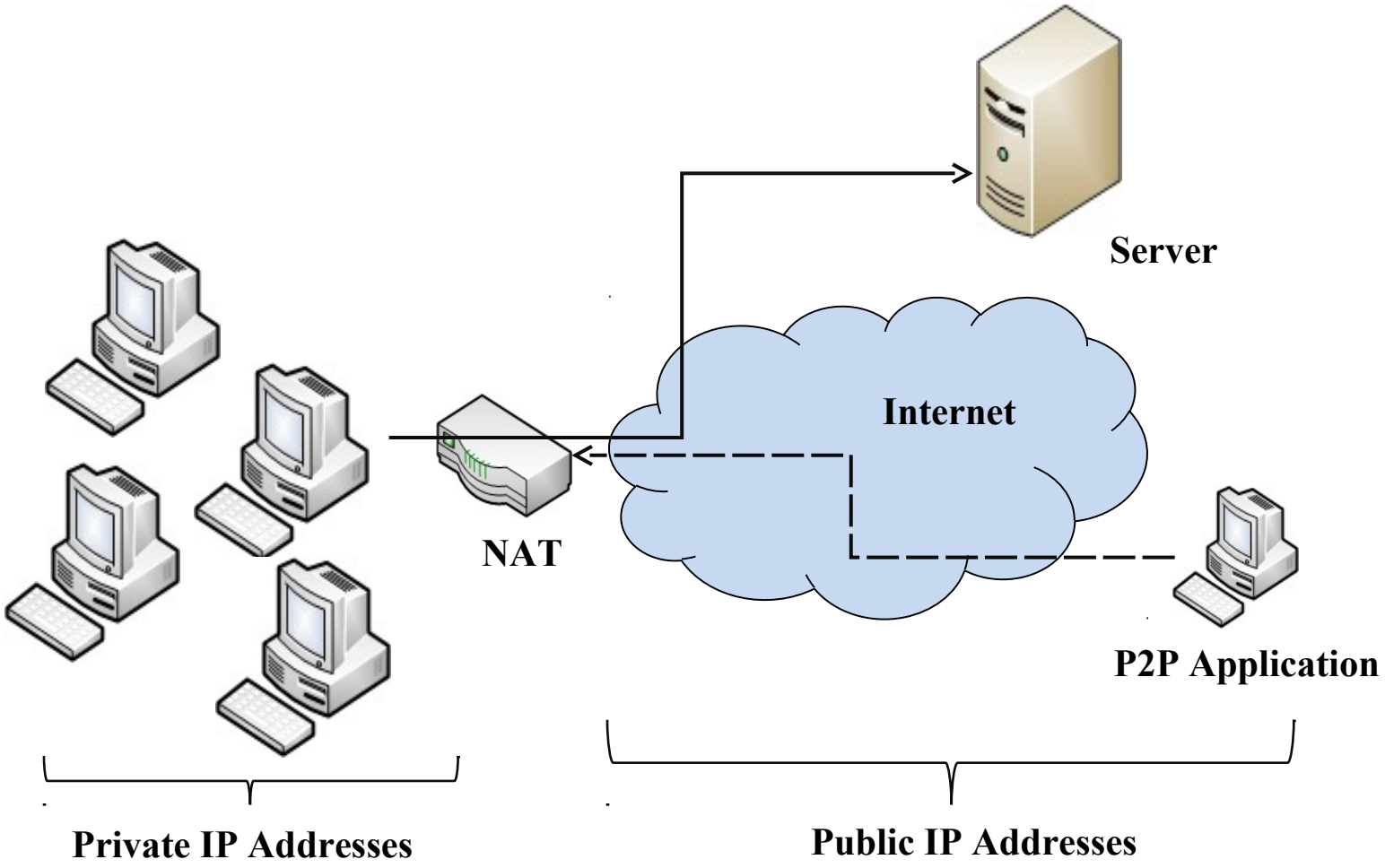


Inside Local IP Address	Inside Global IP Address
10.0.0.1	171.69.58.80
10.0.0.2	171.69.58.81

Continued…

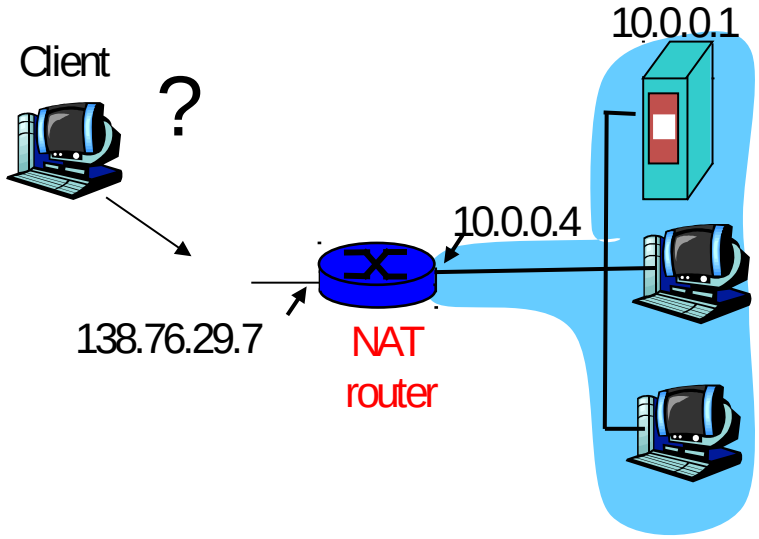

NAT translation table
WAN side addr
LAN side addr
138.76.29.7, 5001
10.0.0.1, 3345
……
……
S: 10.0.0.1, 3345
D: 128.119.40.186, 80
1
10.0.0.1
2
S: 138.76.29.7, 5001
D: 128.119.40.186, 80
10.0.0.4
10.0.0.2
138.76.29.7
S: 128.119.40.186, 80
D: 10.0.0.1, 3345
4
S: 128.119.40.186, 80
D: 138.76.29.7, 5001
3
10.0.0.3

Effect of NATing on P2P



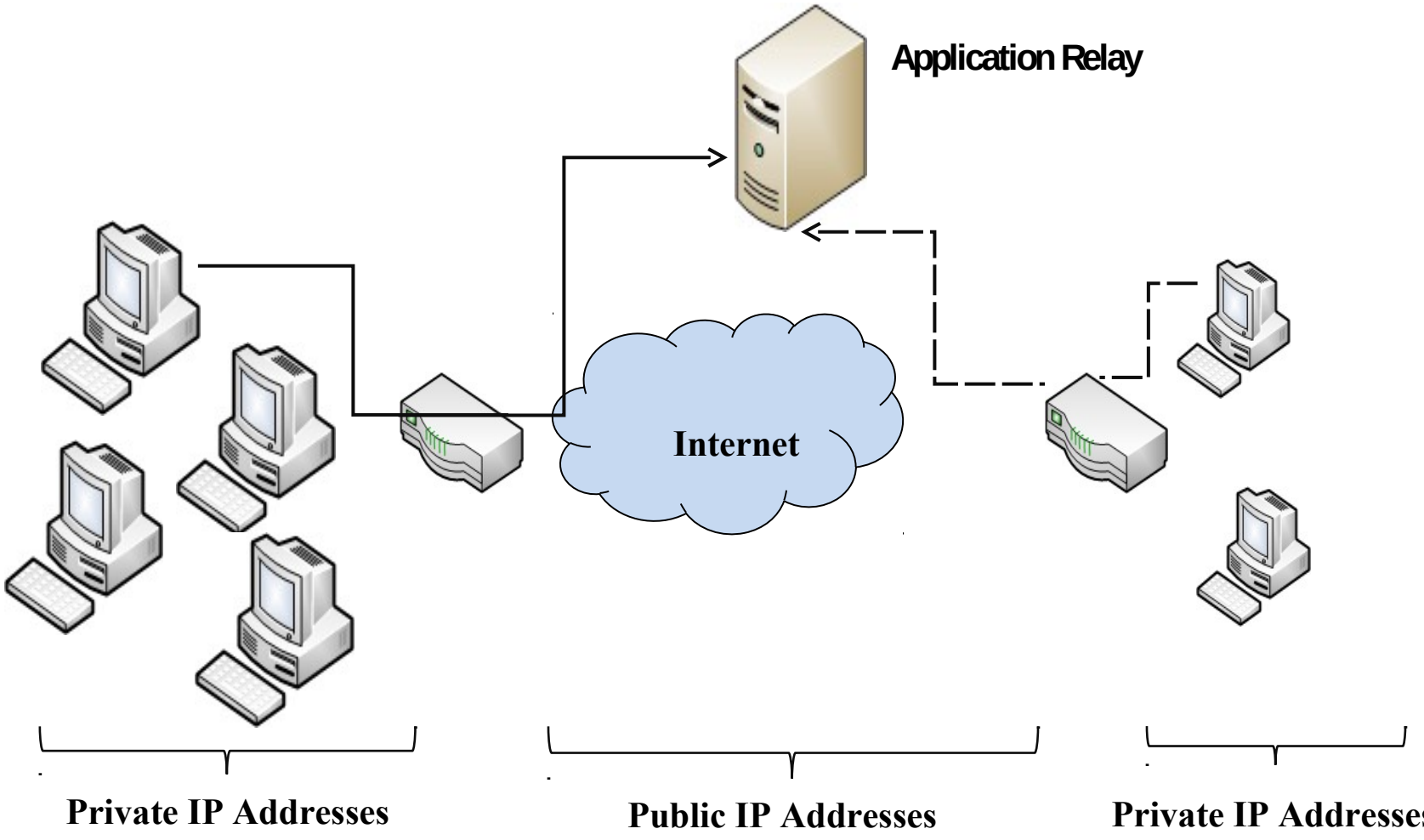
NAT Traversal: Static Routes

- client wants to connect to server with address 10.0.0.1
- Solution : statically configure NAT to forward incoming connection requests at given port to server
  - e.g., (138.76.29.7, port 2500) always forwarded to 10.0.0.1 port 25000



P2P
VoIP
Video game consoles

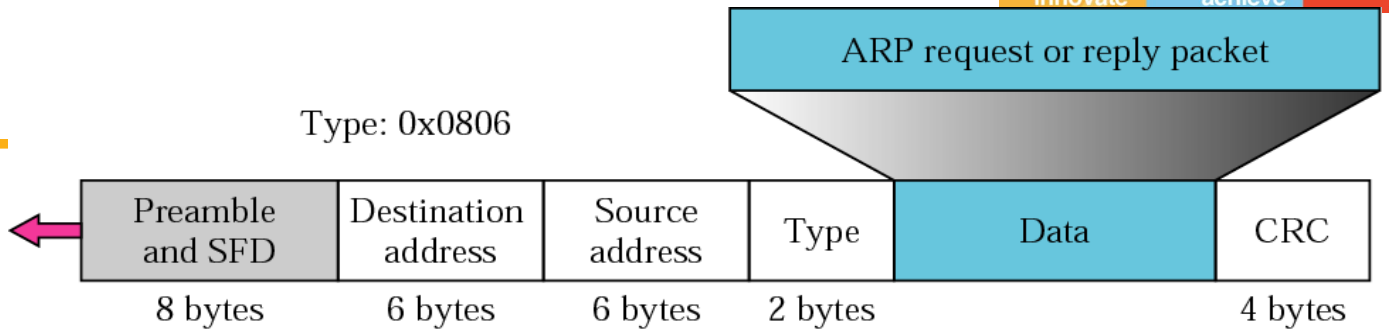
NAT Traversal: Application Relay

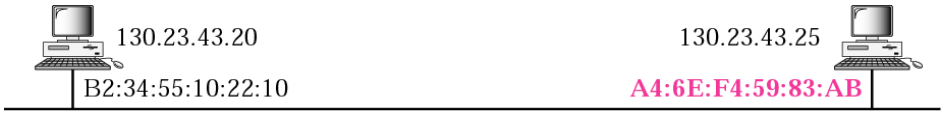


How to Bootstrap an End host?

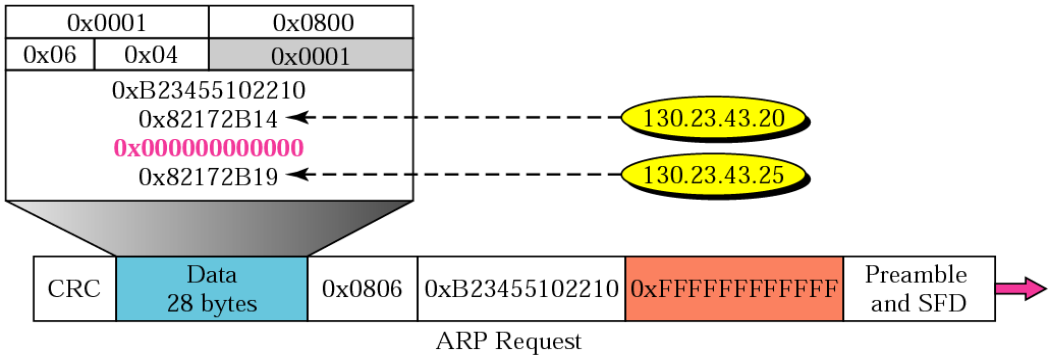
- What IP address the host should use?
- What local Domain Name System server to use?
- ARP, DHCP

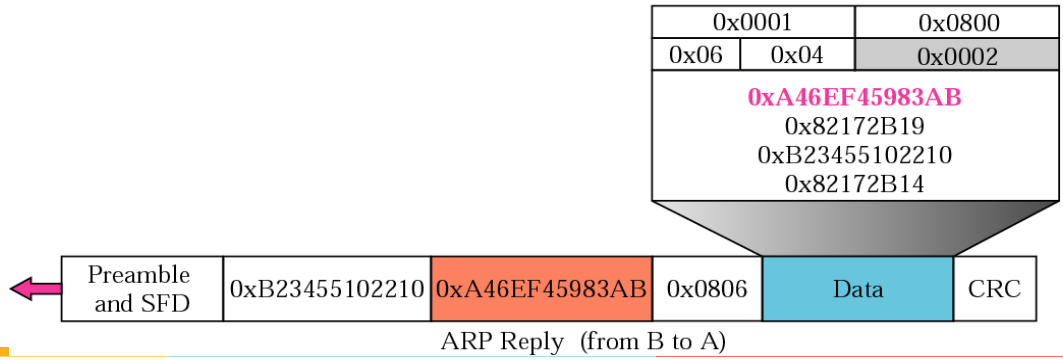
ARP



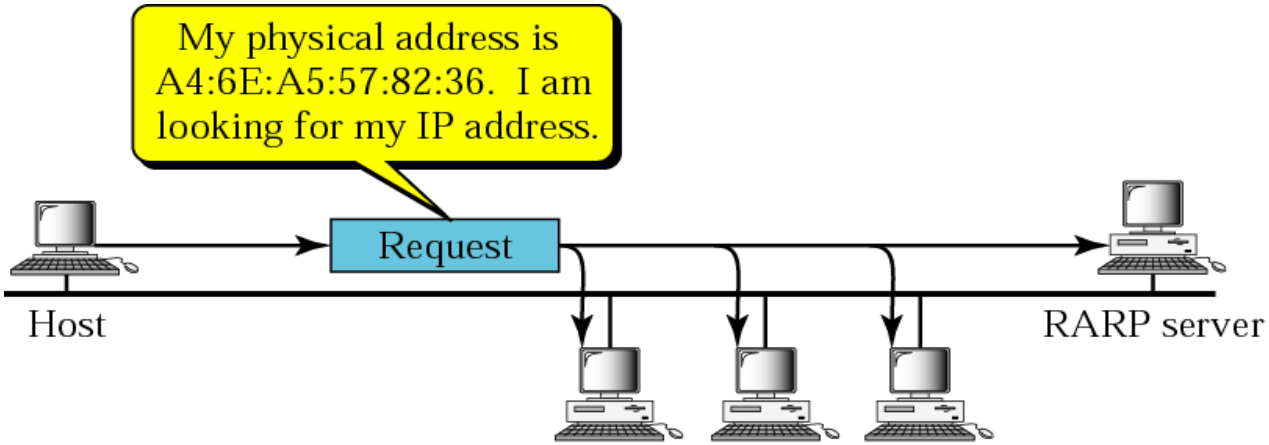


Hardware Type		Protocol Type
Hardware length	Protocol length	Operation Request 1, Reply 2
Sender hardware address (For example, 6 bytes for Ethernet)		
Sender protocol address (For example, 4 bytes for IP)		
Target hardware address (For example, 6 bytes for Ethernet) (It is not filled in a request)		
Target protocol address (For example, 4 bytes for IP)		

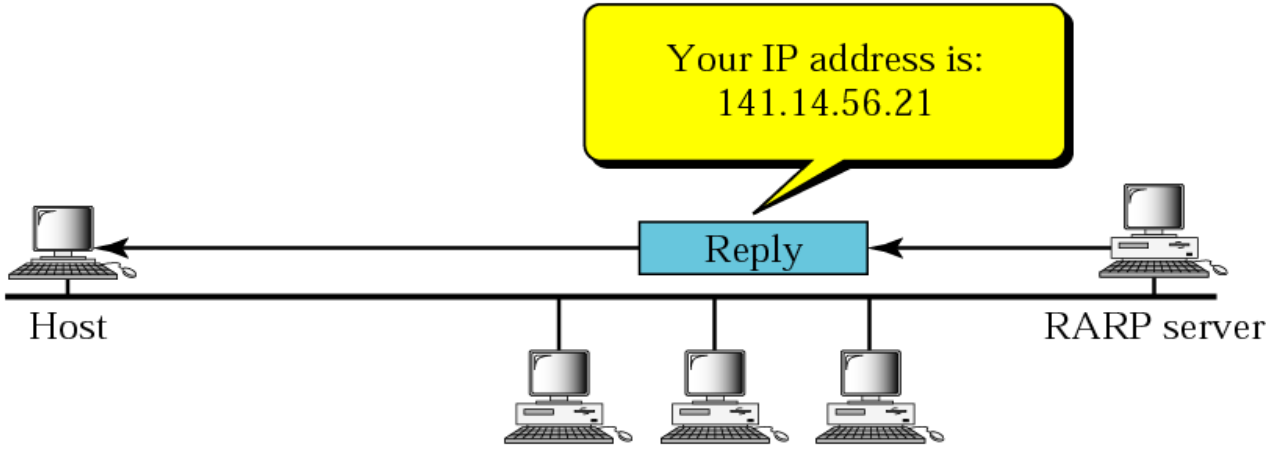




Reverse ARP

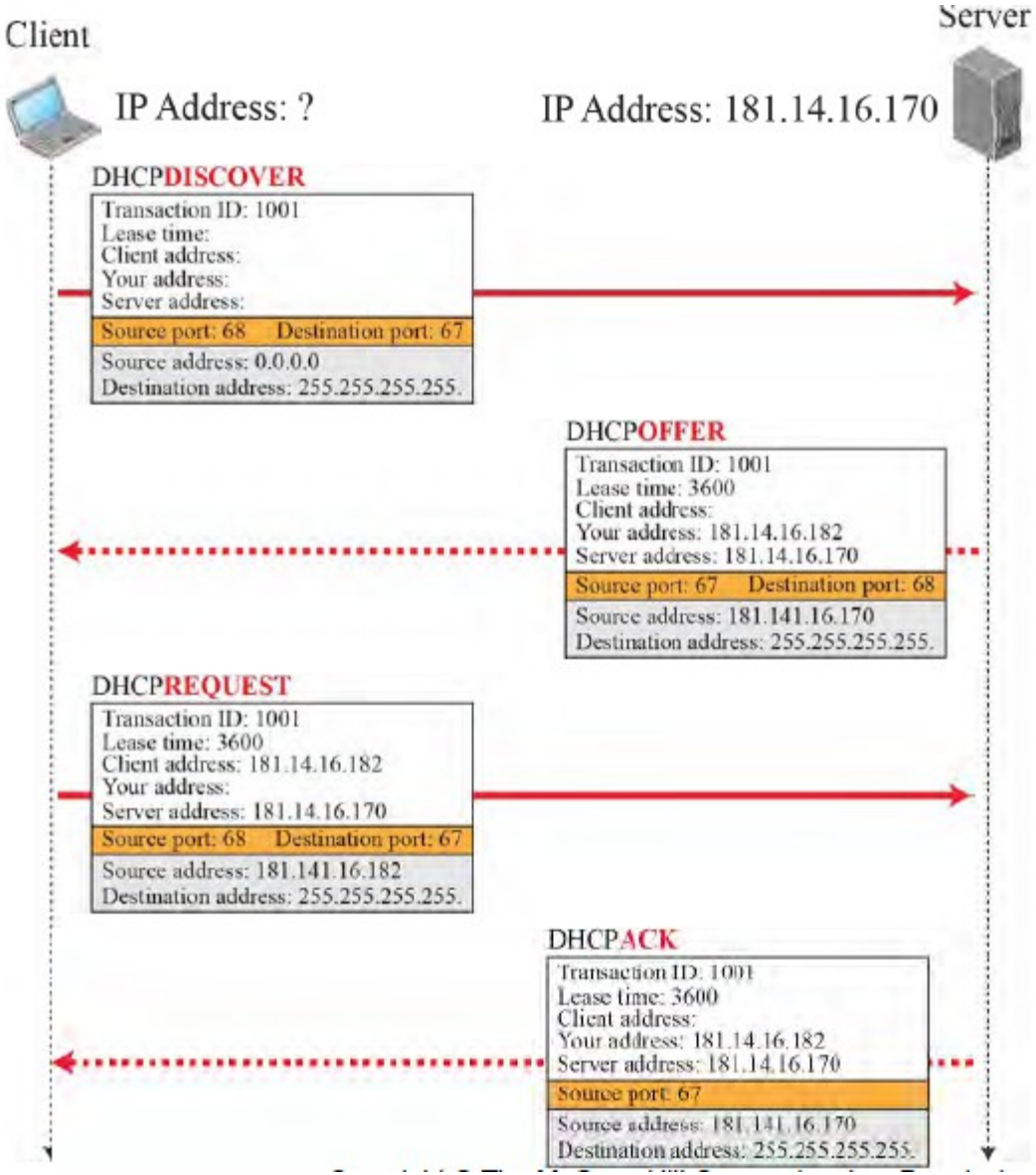


a. RARP request is broadcast



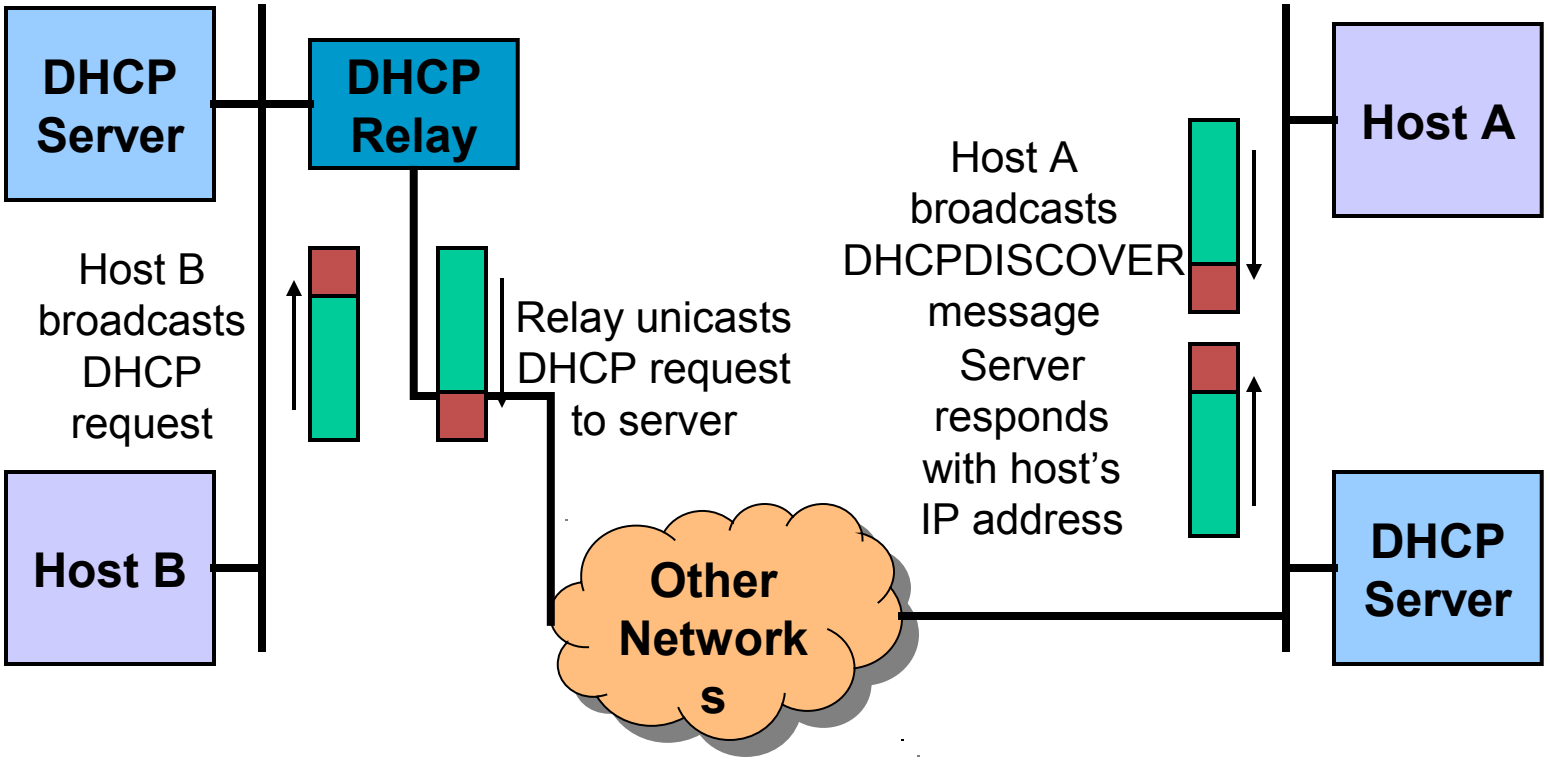
b. RARP reply is unicast

Dynamic Host Configuration Protocol (DHCP)

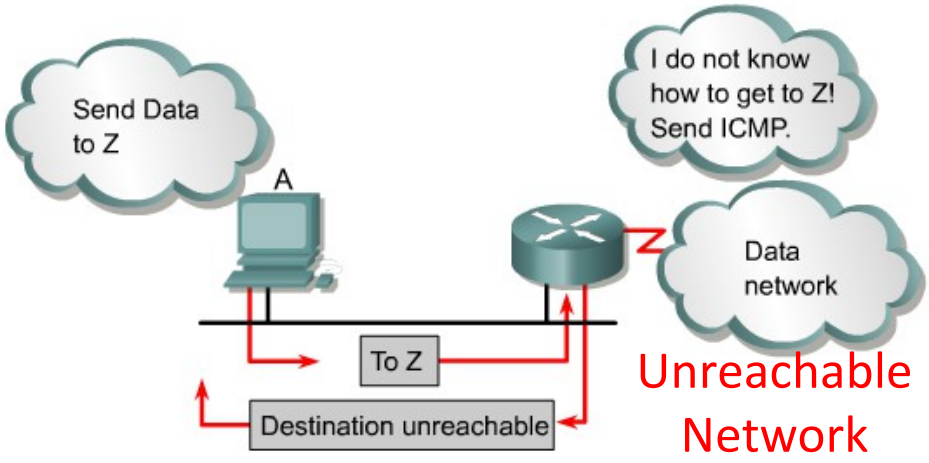


- Client sends Discover "Someone send me an address". This is a broadcast.
- Servers Offer "Use this address".
- Client Requests "I'll use this one". (broadcast)
- Servers Acknowledge "OK or No Way!" (ACK/NAK)

DHCP Relay

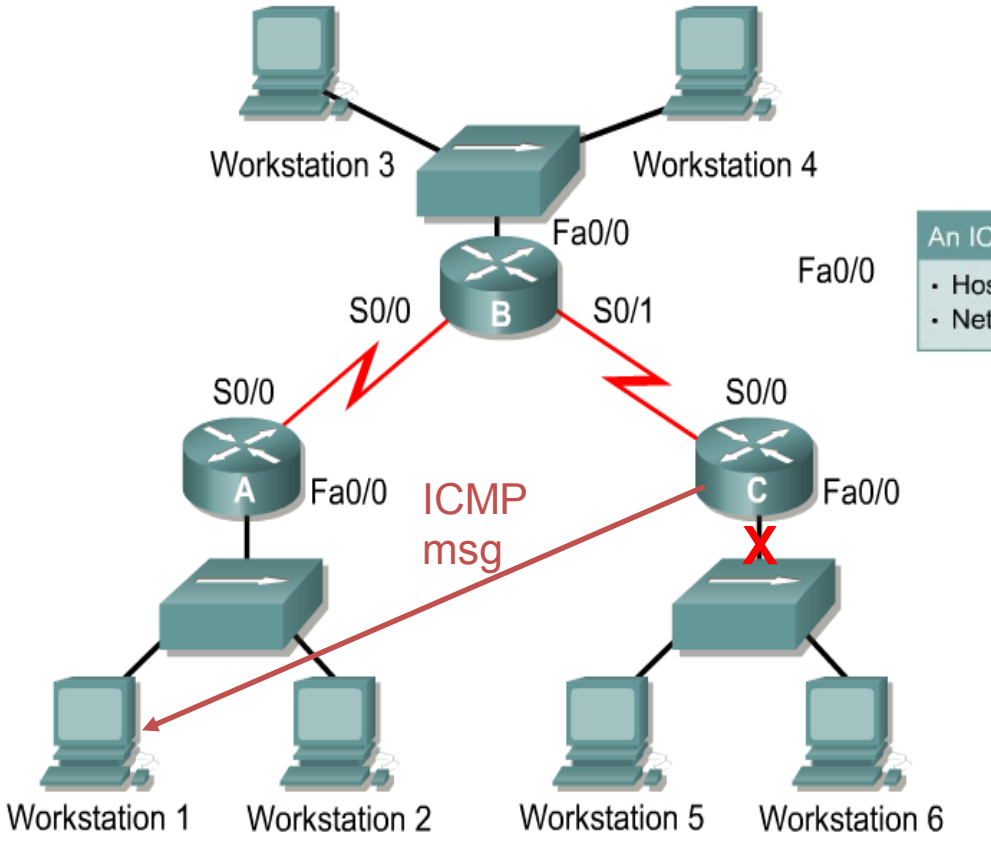

DHCP Server
DHCP Relay
Host A
Host B broadcasts DHCP request
Relay unicasts DHCP request to server
Host A broadcasts DHCPDISCOVER message
Server responds with host's IP address
Host B
Other Networks
DHCP Server

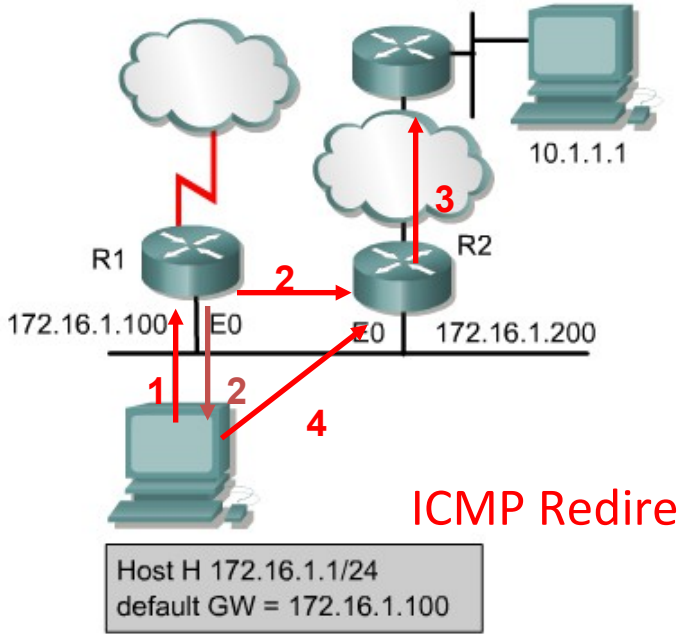
ICMP



An ICMP destination unreachable meassage is sent if:

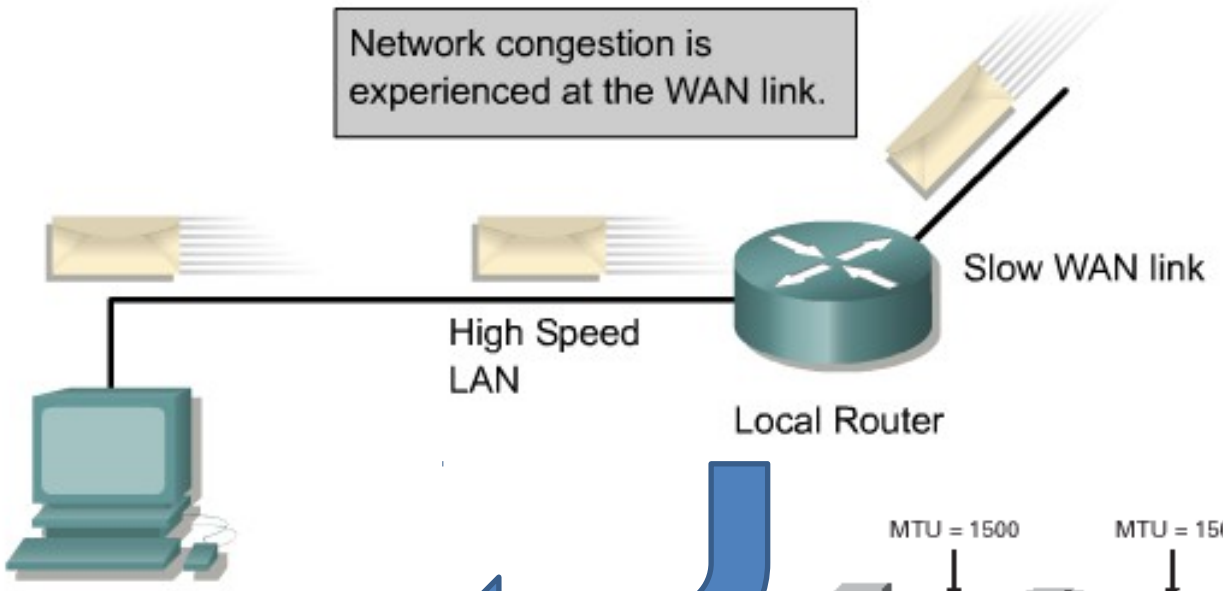
- Host or port unreachable
- Network unreachable



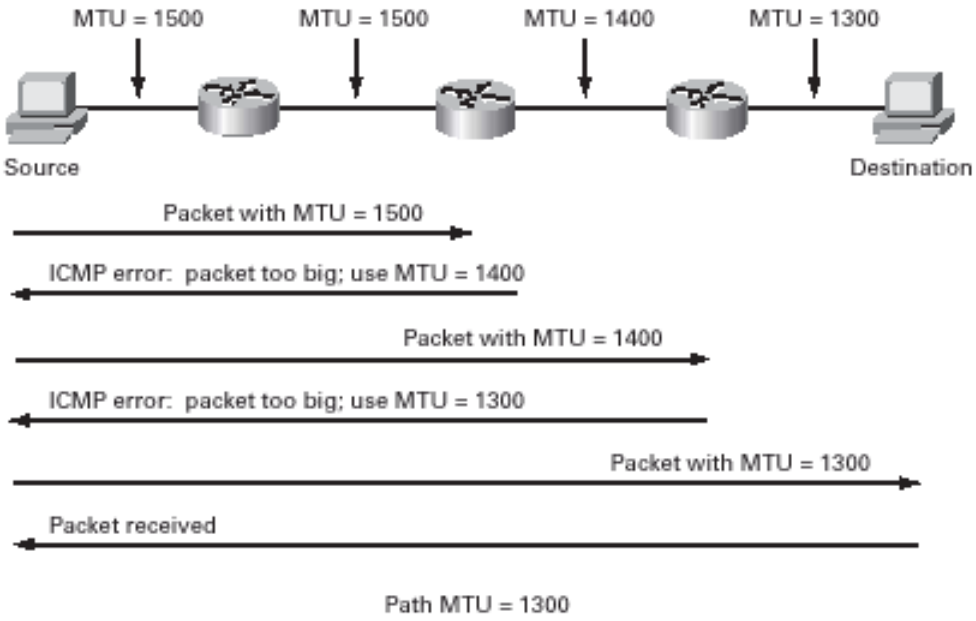


Error Reporting

Continued…



ICMP Source Quench

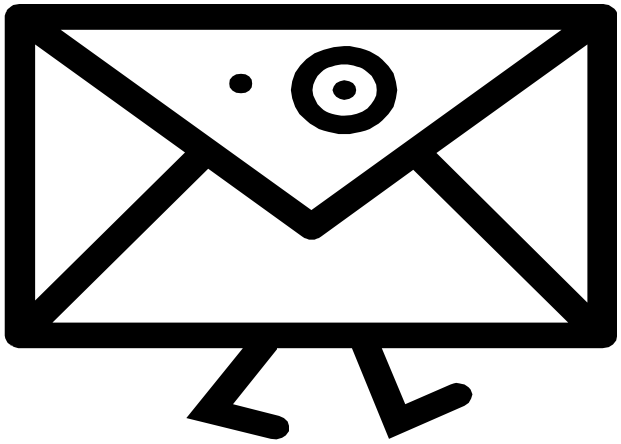


Path MTU Discovery

Routing

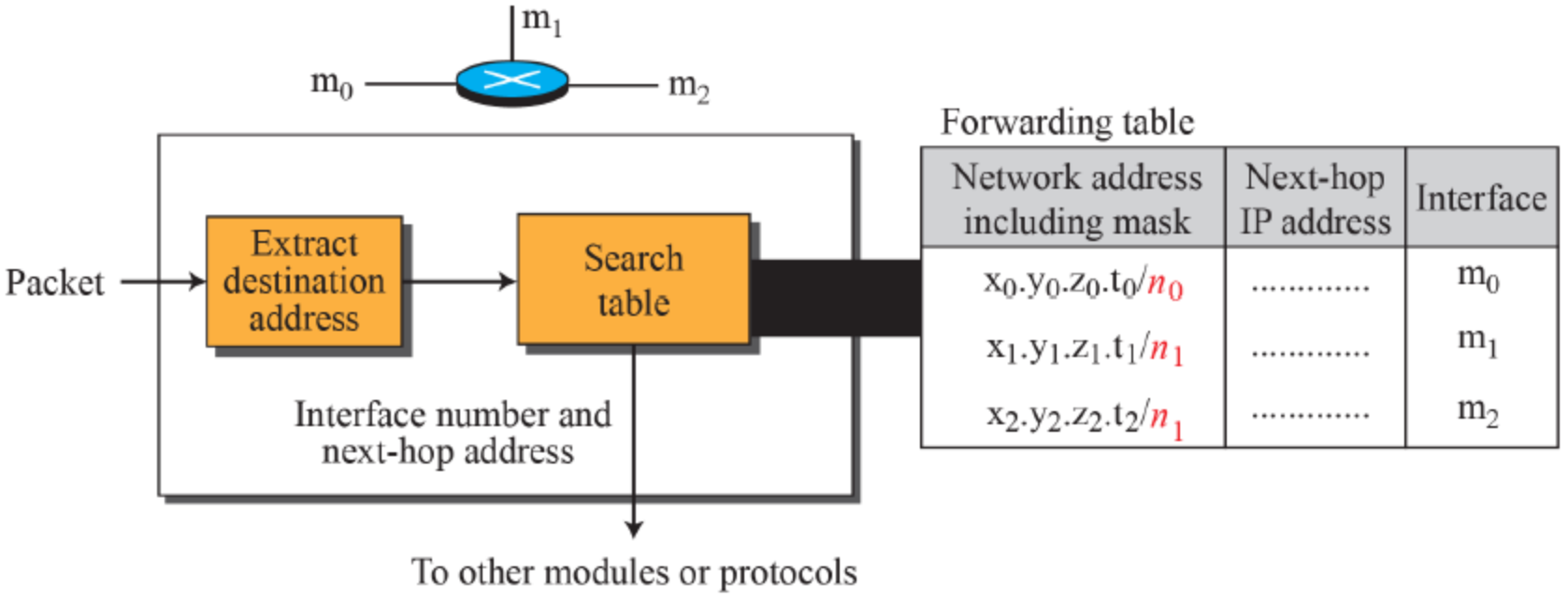
- A famous quotation from RFC 791

  “A name indicates what we seek. An address indicates where it is. A route indicates how we get there.” -- Jon Postel



Packet forwarding

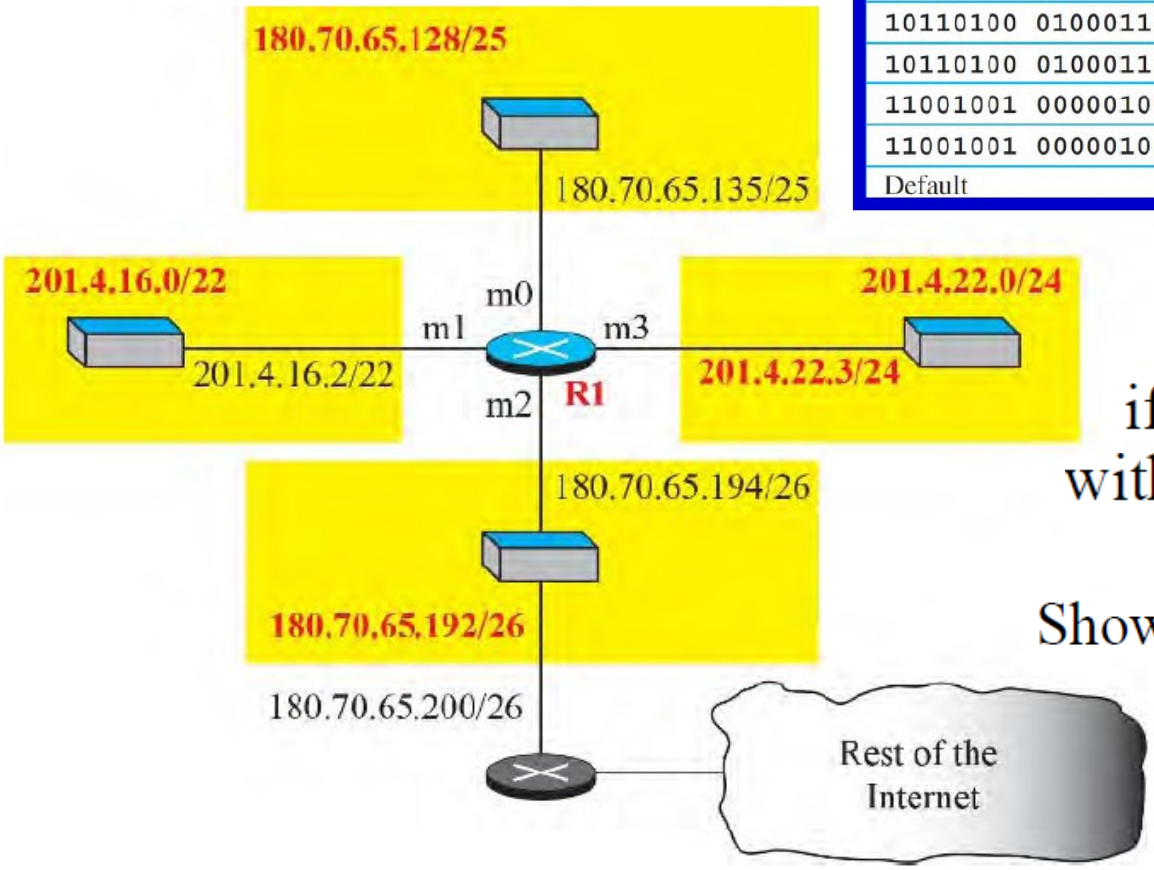
- There's no such thing as a free lunch
  - CIDR allows efficient use of the limited address space
  - But, CIDR makes packet forwarding much harder



An Example

Network address/mask	Next hop	Interface
180.70.65.192/26	—	m2
180.70.65.128/25	—	m0
201.4.22.0/24	—	m3
201.4.16.0/22	—	m1
Default	180.70.65.200	m2

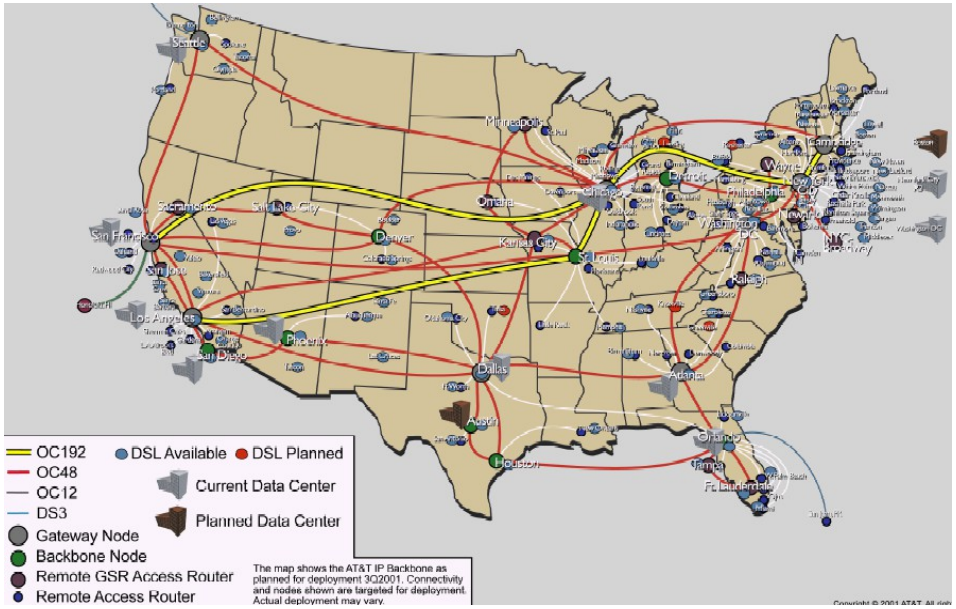
Leftmost bits in the destination address	Next hop	Interface
10110100 01000110 01000001 11	—	m2
10110100 01000110 01000001 1	—	m0
11001001 00000100 00011100	—	m3
11001001 00000100 000100	—	m1
Default	180.70.65.200	m2



if a packet arrives at R1 with the destination address 180.70.65.140 Show the forwarding process

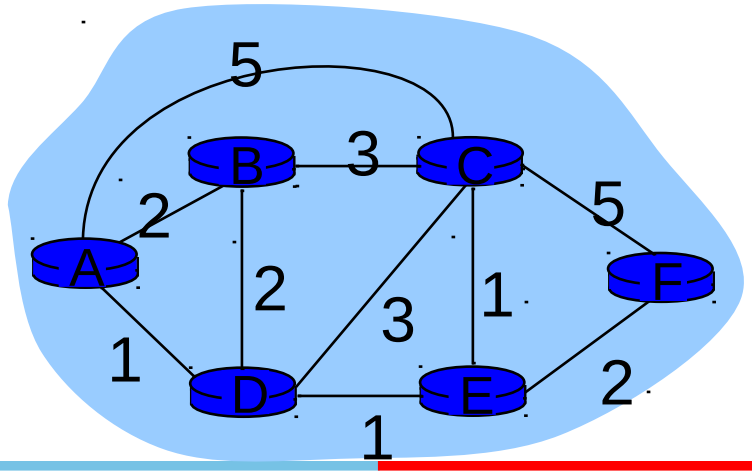
Network Layer Routing

Goal: determine "good" paths (sequences of routers) through network from sources to destination.



Graph abstraction for the routing problem:

- graph nodes are routers
- graph edges are physical links
  - links have properties: delay, capacity, cost, policy



Routing algorithm Classification

Global or decentralized?

Global:

- all routers have complete topology, link cost info
- "link state" algorithms

Decentralized:

- router knows physically-connected neighbors
- iterative process of computation, exchange of info with neighbors
- "distance vector" algorithms

Static or dynamic?

Static:

- routes change slowly over time

Dynamic:

- routes change more quickly
  - periodic update
  - in response to link cost changes