Lecture 4
IP addressing

A Part of the Chapter 4 The Network Layer: Data Plane 305

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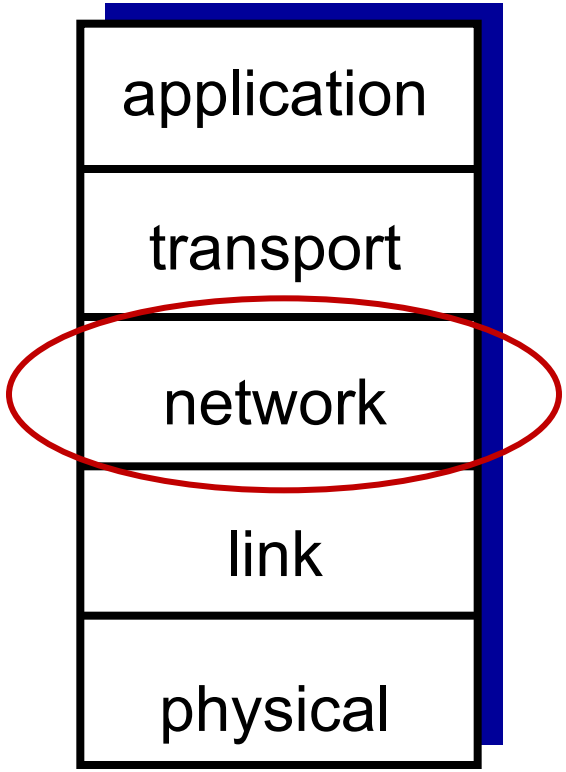
2. IP addresses
3. IP subnetting technique and CIDR

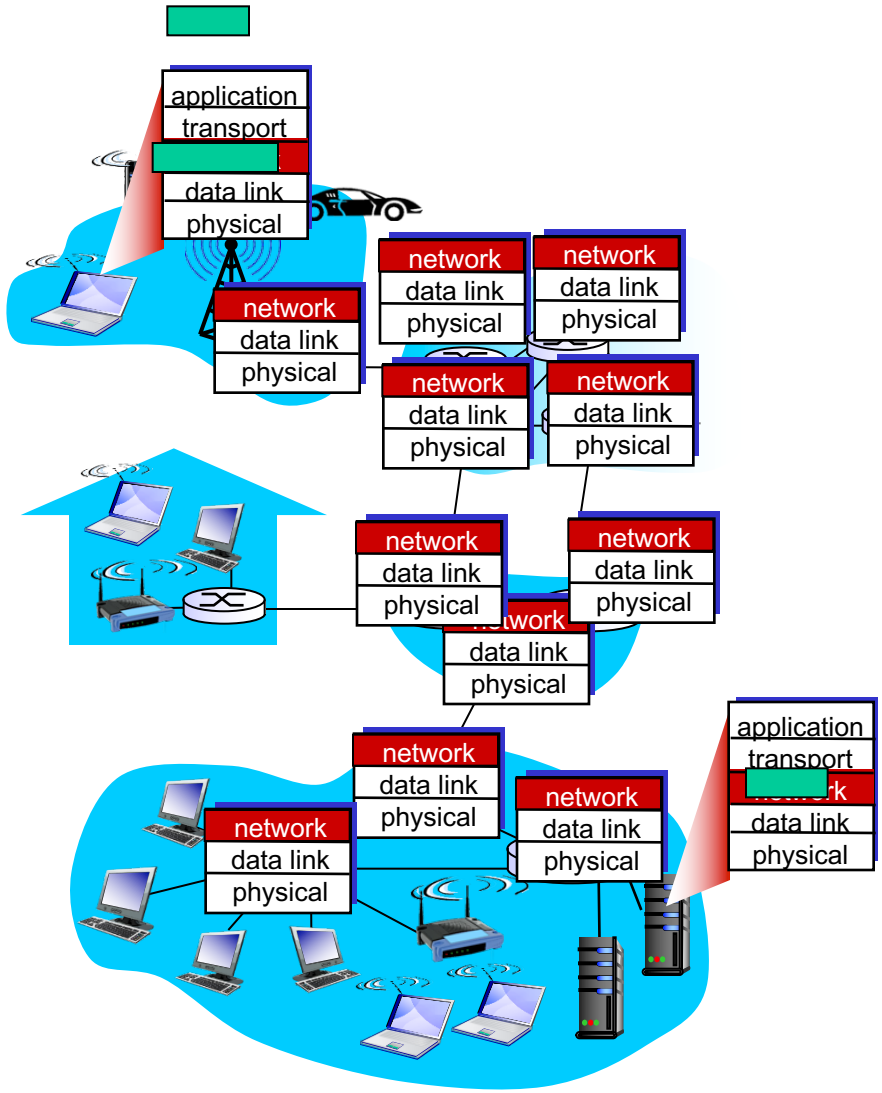
1. Introduction

Internet protocol stack

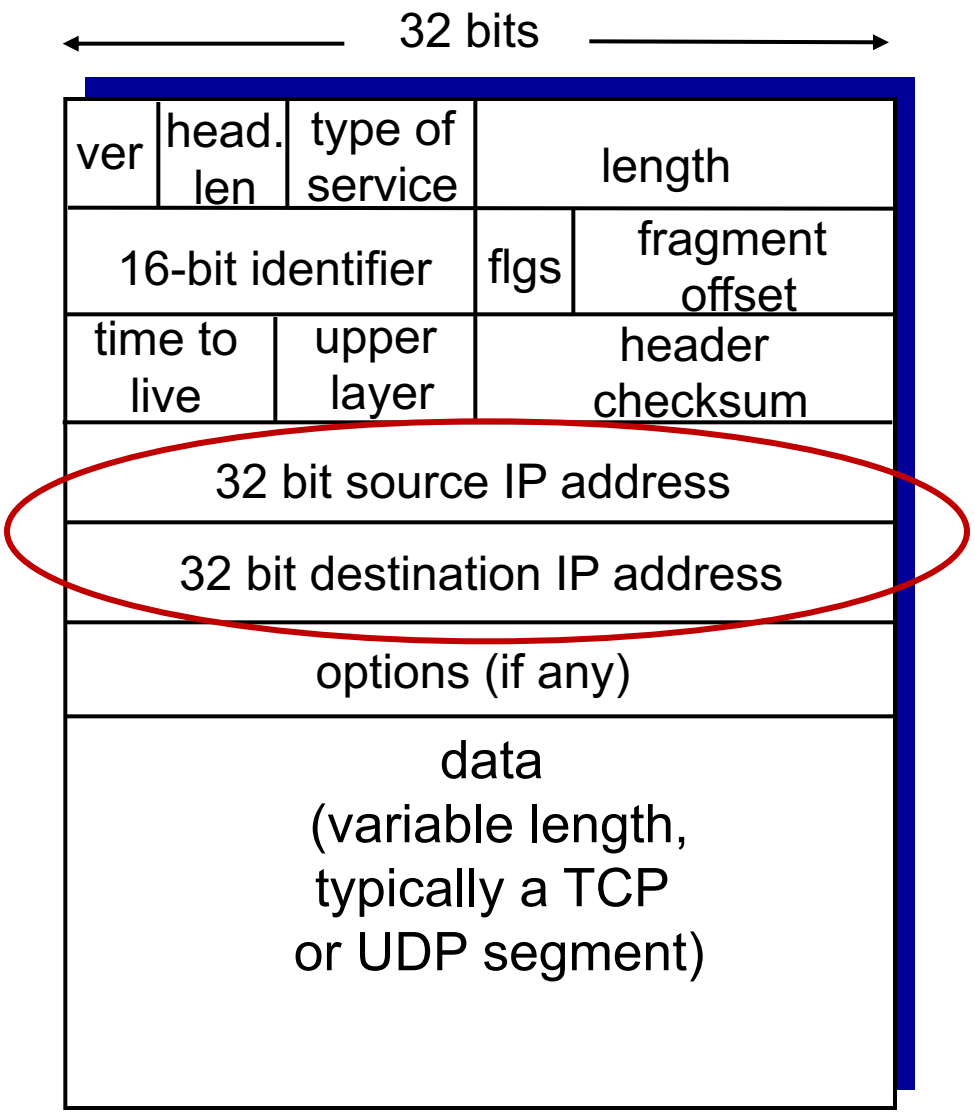


Network layer

- network layer protocols in every host, router
- router examines header fields in all IP datagrams passing through it



IP datagram format



Binary to Decimal Review

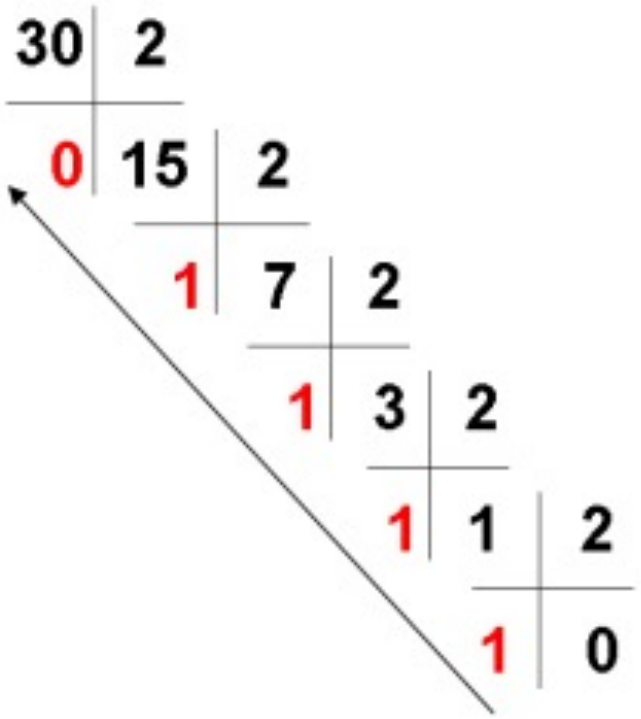
2^7 128	2^6 64	2^5 32	2^4 16	2^3 8	2^2 4	2^1 2	2^0 1	
1	1	1	1	1	1	1	1	255
0	1	1	1	1	1	1	1	127
1	1	0	0	0	0	0	0	192
1	0	1	1	1	1	1	1	191
1	1	0	1	1	1	1	1	223
1	1	1	0	0	0	0	0	224

Binary (2) <-> Decimal (10)

$$1010110_2$$

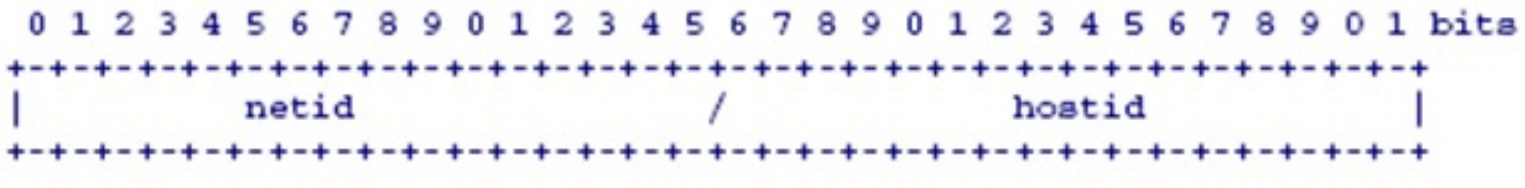
$$
\begin{aligned}
1 * 2^6 &= 1 * 64 = 64 \\
+\,0 * 2^5 &= 0 * 32 = 0 \\
+\,1 * 2^4 &= 1 * 16 = 16 \\
+\,0 * 2^3 &= 0 * 8 = 0 \\
+\,1 * 2^2 &= 1 * 4 = 4 \\
+\,1 * 2^1 &= 1 * 2 = 2 \\
+\,0 * 2^0 &= 0 * 1 = 0 \\
&\qquad\qquad 86_{10}
\end{aligned}
$$

$$30_{10} = 11110_2$$

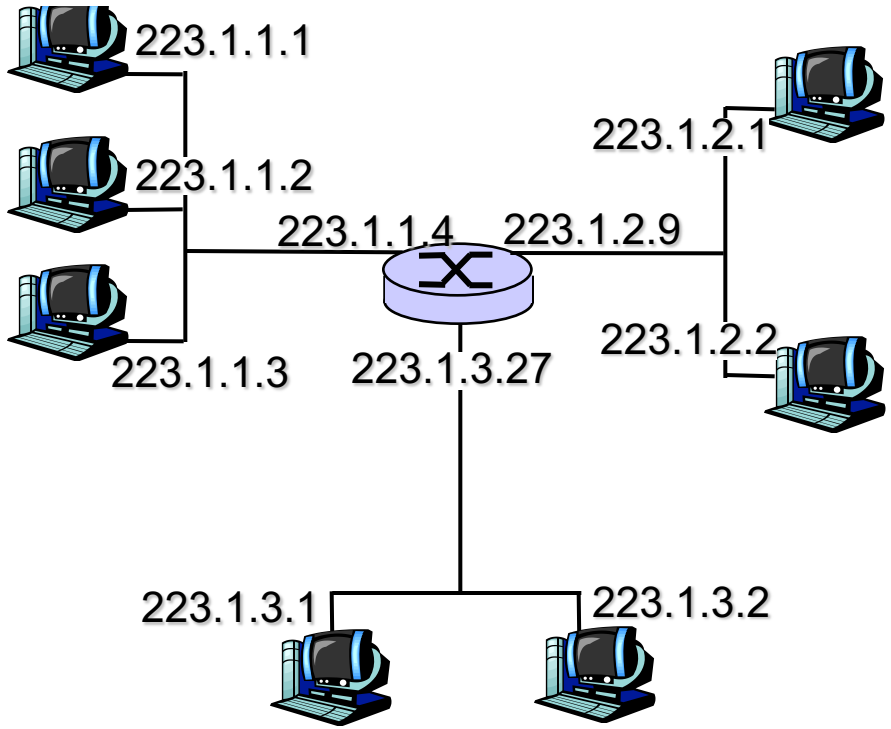


2. IP addreses

IP Addresses (RFC 791)



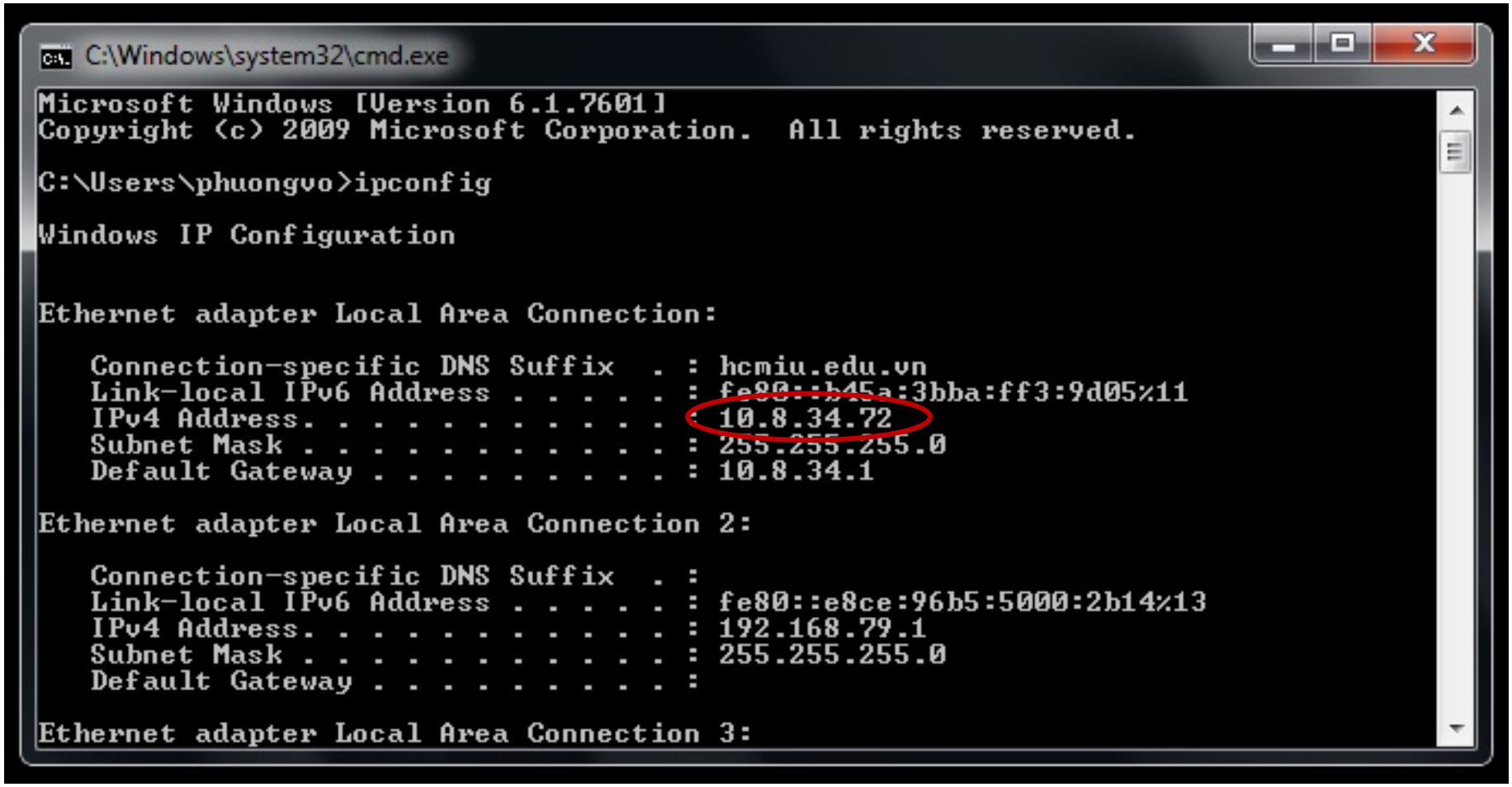
- IP address is a unique 32-bit number (04 bytes in decimal).
- Netid identifies the network.
- Hostid identifies the host within the network.
- IP addresses associated with each interface.



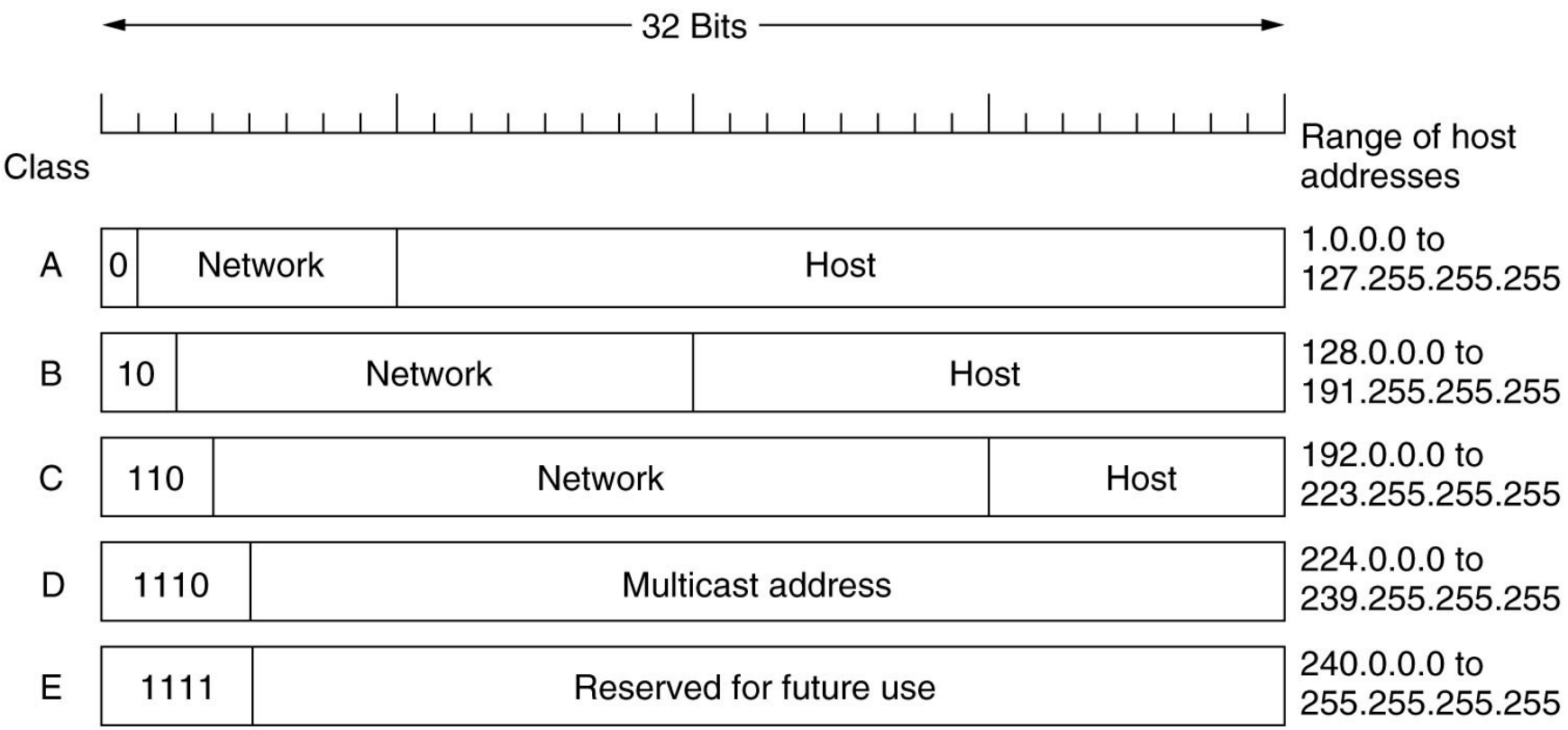
223.1.1.1 = 11011111 00000001 00000001 00000001

223 1 1 1

IP Address of Your Computer



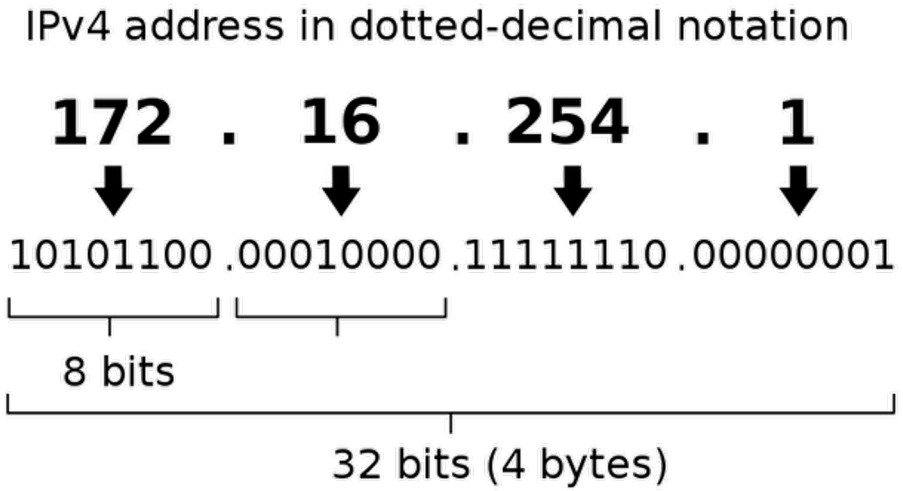
IP Address Classes



Examples

What are the classes of the following IP addresses:

- 203.162.8.2
- 111.65.248.132 (vnexpress.net)
- 134.170.185.46 (microsoft.com)
- 72.163.4.161 (cisco.com)



Special addresses

- Each network has two special address: network and broadcast addresses which cannot be used for a physical interface

netid	hostid	meaning
xxx	All 0	Identifies a network. It is used in routing tables.
xxx	All 1	Broadcast in the networks xxx.
All 0	All 0	Identifies "this host" in "this net". Used as source address in configuration protocols, e.g., DHCP.
All 1	All 1	Broadcast in "this net". Used as destination address in configuration protocols, e.g. DHCP.
127	xxx	Loopback: interprocess communication with TCP/IP.

Class A Addresses

- Structure
  - Network.*node.node.node*

    8 bits 24 bits
- Class A Valid Host IDs
  - 10.*0.0.0* All host bits *off*
  - 10.*255.255.255* All host bits *on*
  - Valid hosts = 10.*0.0.1* - 10.*255.255.254*

    • $2^{24} - 2 = 16,777,216 - 2 = 16,777,214$ valid hosts

Class B Addresses

- Structure
  - Network.Network.*node.node*

    16 bits 16 bits
- Class B Valid Host IDs
  - 172.16.*0.0* All host bits *off*
  - 172.16.*255.255* All host bits *on*
  - Valid hosts = 172.16.*0.1* - 172.16.*255.254*

    • $2^{16} - 2 = 65536 - 2 = 65534$ valid hosts

Class C Addresses

- Structure
  - Network.Network.Network.*node*

    8 bits 8 bits
- Class C Valid Host IDs
  - 192.168.100.*0* All host bits *off*
  - 192.168.100.*255* All host bits *on*
  - Valid hosts = 192.168.100.*1* - 192.168.100.*254*

    • 2^8-2 = 256 – 2 = 254 valid hosts

IP addresses

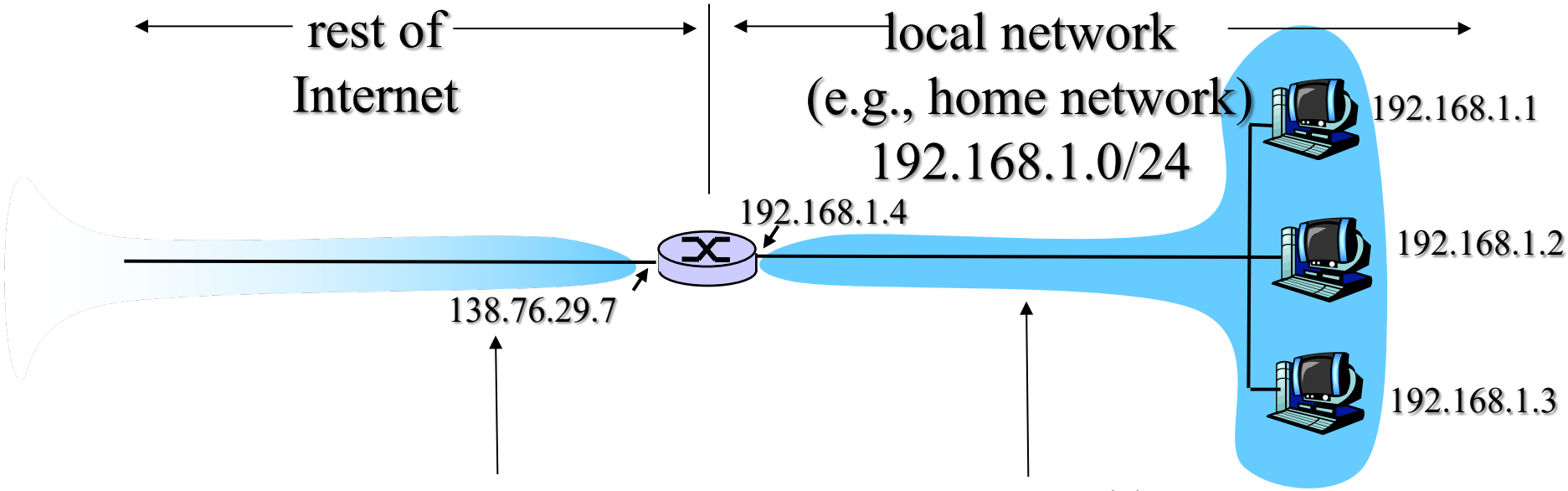
- Internet assigned number authority (IANA) assigns address blocks to Regional Internet Registries (RIR) :
  - RIPE: Europe
  - ARIN: USA
  - APNIC: Asia
  - LACNIC: Latin
- RIR assigns addresses to ISPs and ISPs assign addresses to their customers

Private IP Addresses (RFC 1918)

Address Class	Reserved address space
Class A	10.0.0.0 through 10.255.255.255
Class B	172.16.0.0 through 172.31.255.255
Class C	192.168.0.0 through 192.168.255.255

- The Internet Assigned Numbers Authority (IANA) has assigned several address ranges to be used by private networks.
- Non-routable, as it is not unique
- Any private network that needs to use IP addresses internally can use any address within these ranges without any coordination with IANA or an Internet registry

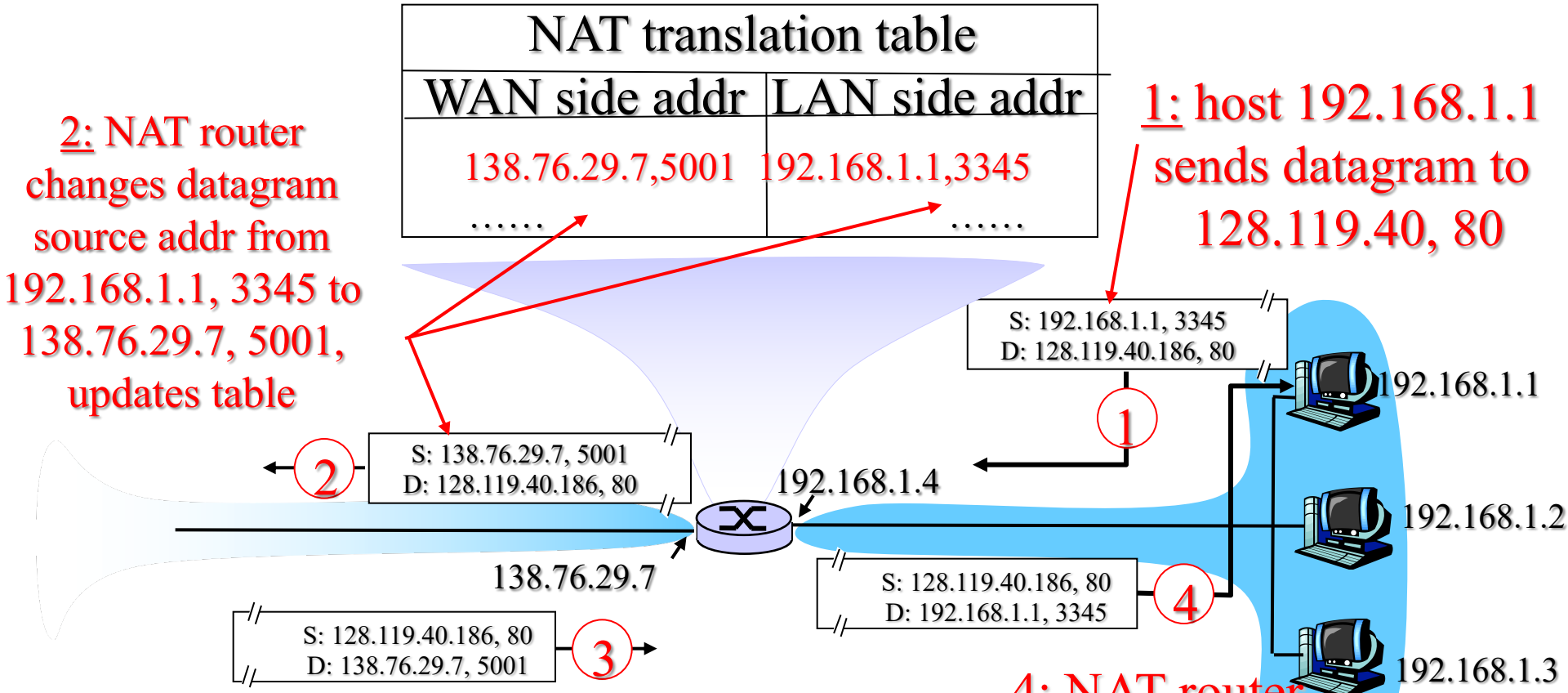
NAT: Network Address Translation



All datagrams *leaving* local network have same single source NAT IP address: 138.76.29.7, different source port numbers

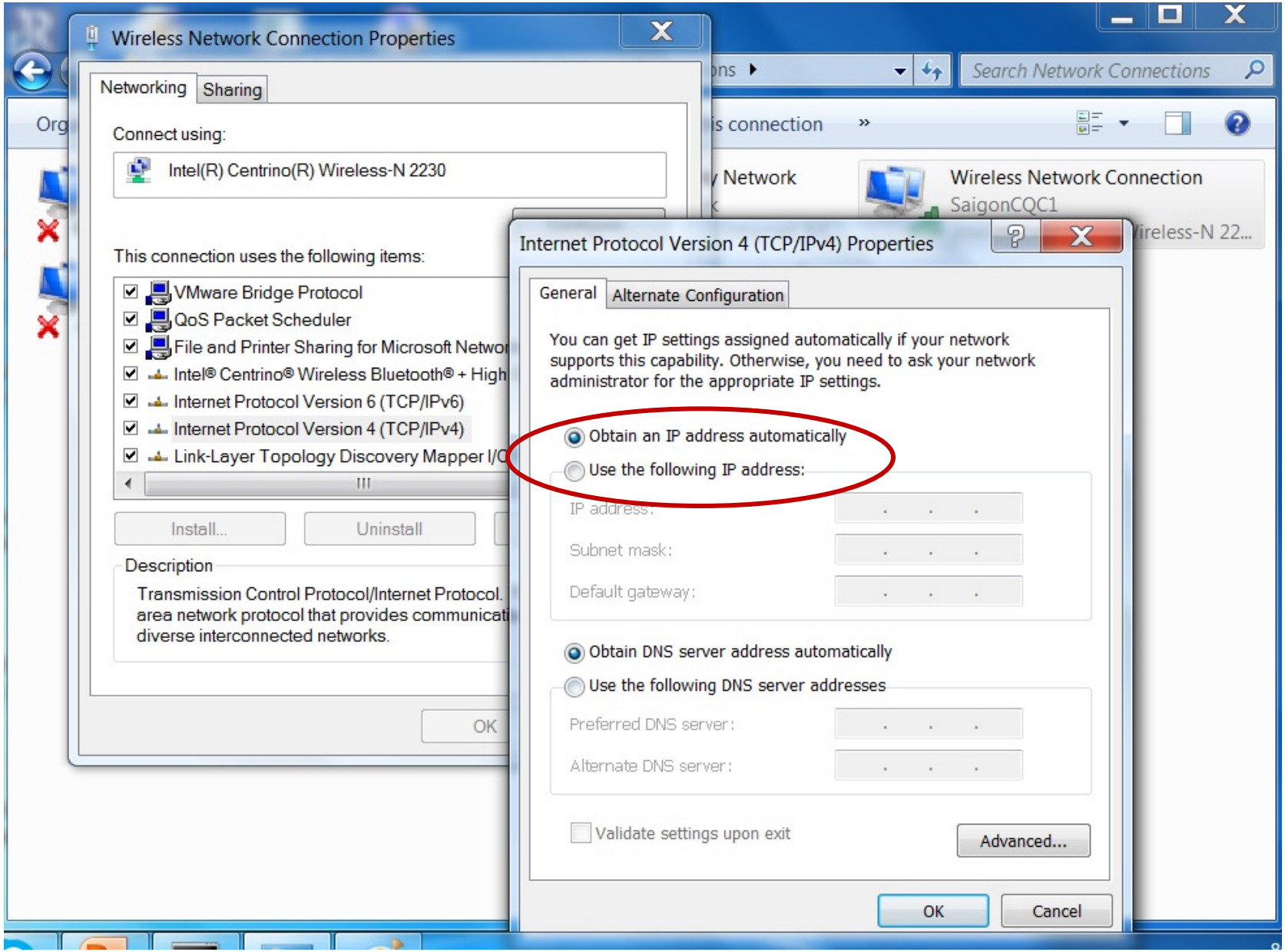
Datagrams with source or destination in this network have 192.168.1.0/24 address for source, destination (as usual)

NAT: Network Address Translation



IP Addresses: How to Get One?

- hard-coded by system admin in a file
- DHCP: Dynamic Host Configuration Protocol: dynamically get address from as server
  - "plug-and-play"


Wireless Network Connection Properties
Networking
Sharing
Connect using:
Intel(R) Centrino(R) Wireless-N 2230
This connection uses the following items:
VMware Bridge Protocol
QoS Packet Scheduler
File and Printer Sharing for Microsoft Networ
Intel® Centrino® Wireless Bluetooth® + High
Internet Protocol Version 6 (TCP/IPv6)
Internet Protocol Version 4 (TCP/IPv4)
Link-Layer Topology Discovery Mapper I/O
Install...
Uninstall
Description
Transmission Control Protocol/Internet Protocol.
area network protocol that provides communicati
diverse interconnected networks.
OK
Search Network Connections
Wireless Network Connection
SaigonCQC1
Internet Protocol Version 4 (TCP/IPv4) Properties
General
Alternate Configuration
You can get IP settings assigned automatically if your network supports this capability. Otherwise, you need to ask your network administrator for the appropriate IP settings.
Obtain an IP address automatically
Use the following IP address:
IP address:
Subnet mask:
Default gateway:
Obtain DNS server address automatically
Use the following DNS server addresses
Preferred DNS server:
Alternate DNS server:
Validate settings upon exit
Advanced...
OK
Cancel

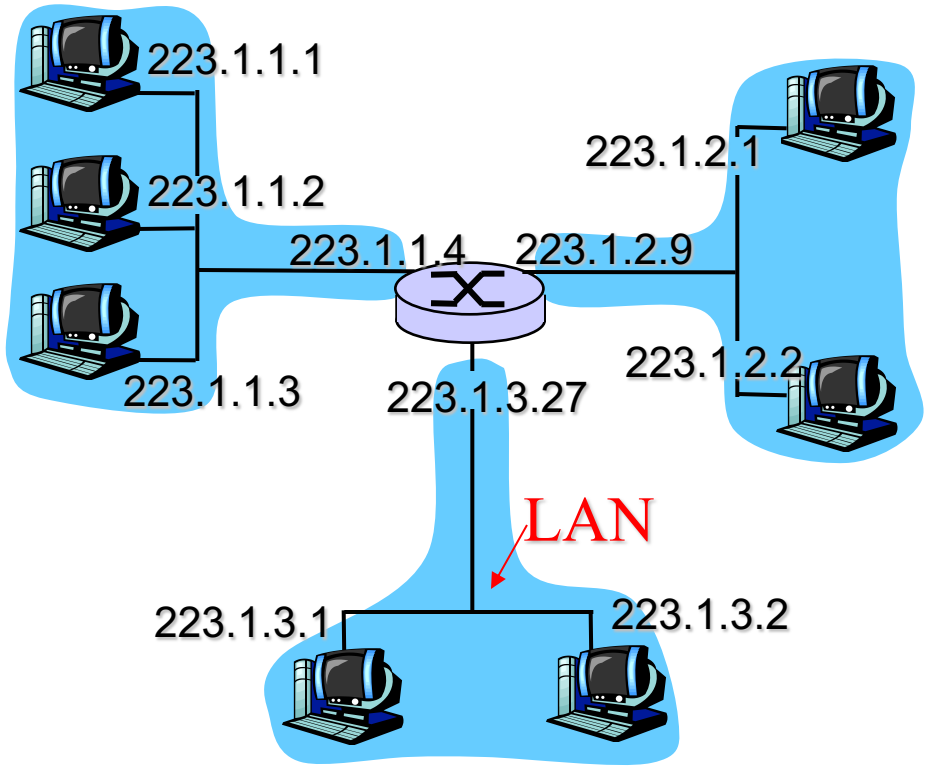
3. Subnetting and CIDR

Two concerns in IP addressing

- Address space utilization
- Scalability in routing

Subnets

- IP address:
  - subnet part (high order bits)
  - host part (low order bits)
- What's a subnet ?
  - device interfaces with same subnet part of IP address
  - can physically reach each other without intervening router

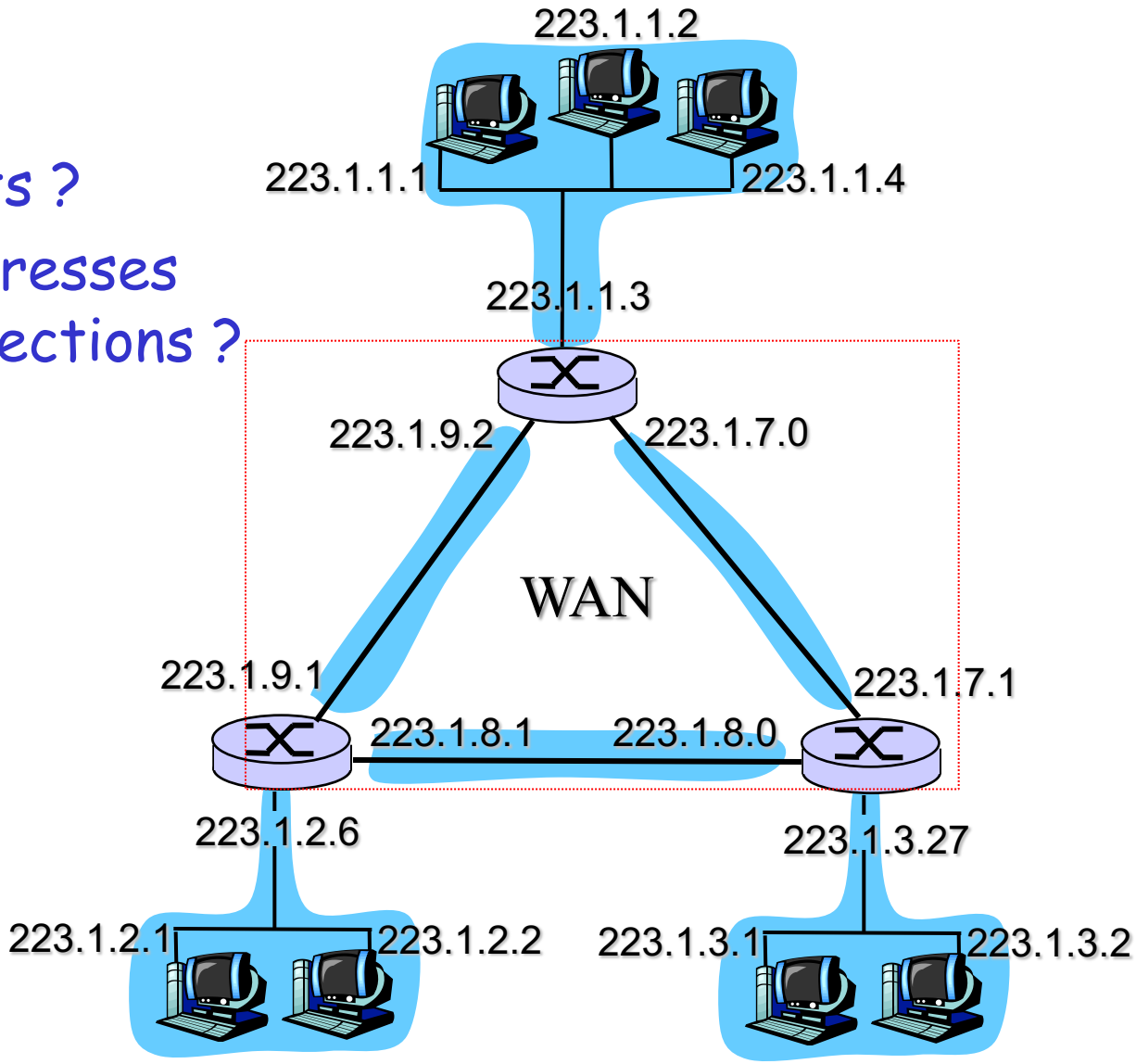


network consisting of 3 subnets

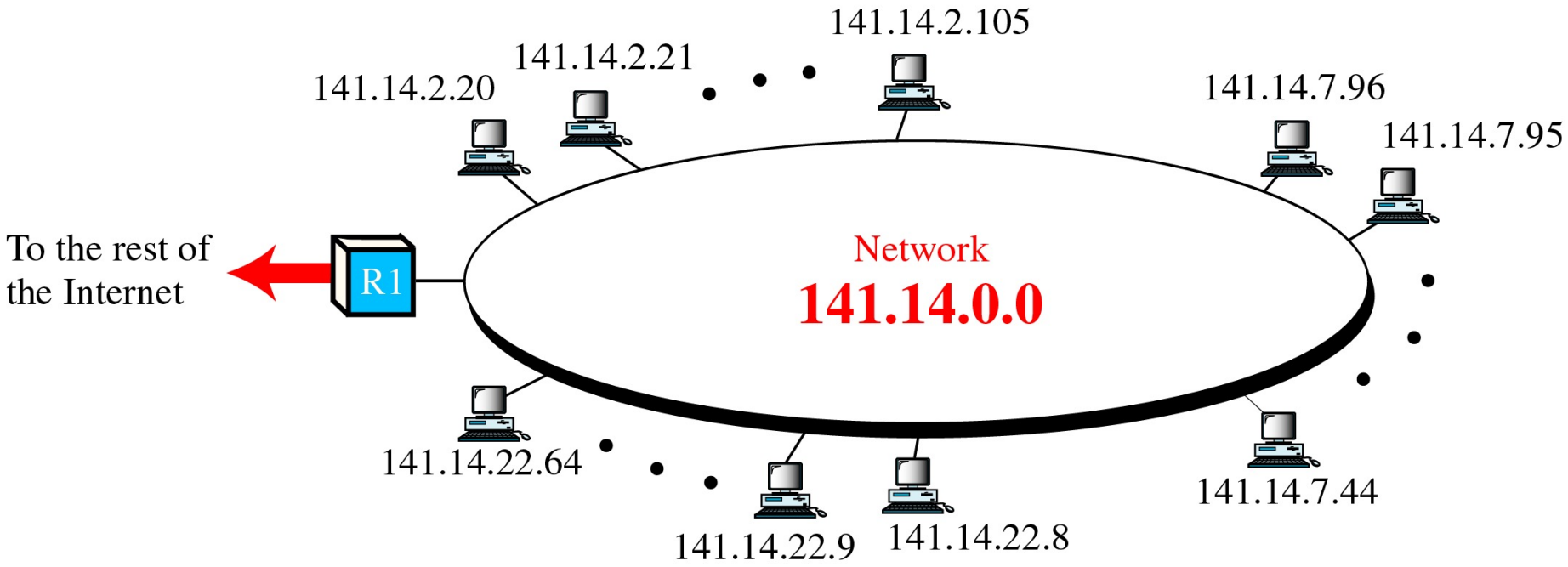
Subnets

How many subnets ?

How many IP addresses for WAN connections ?



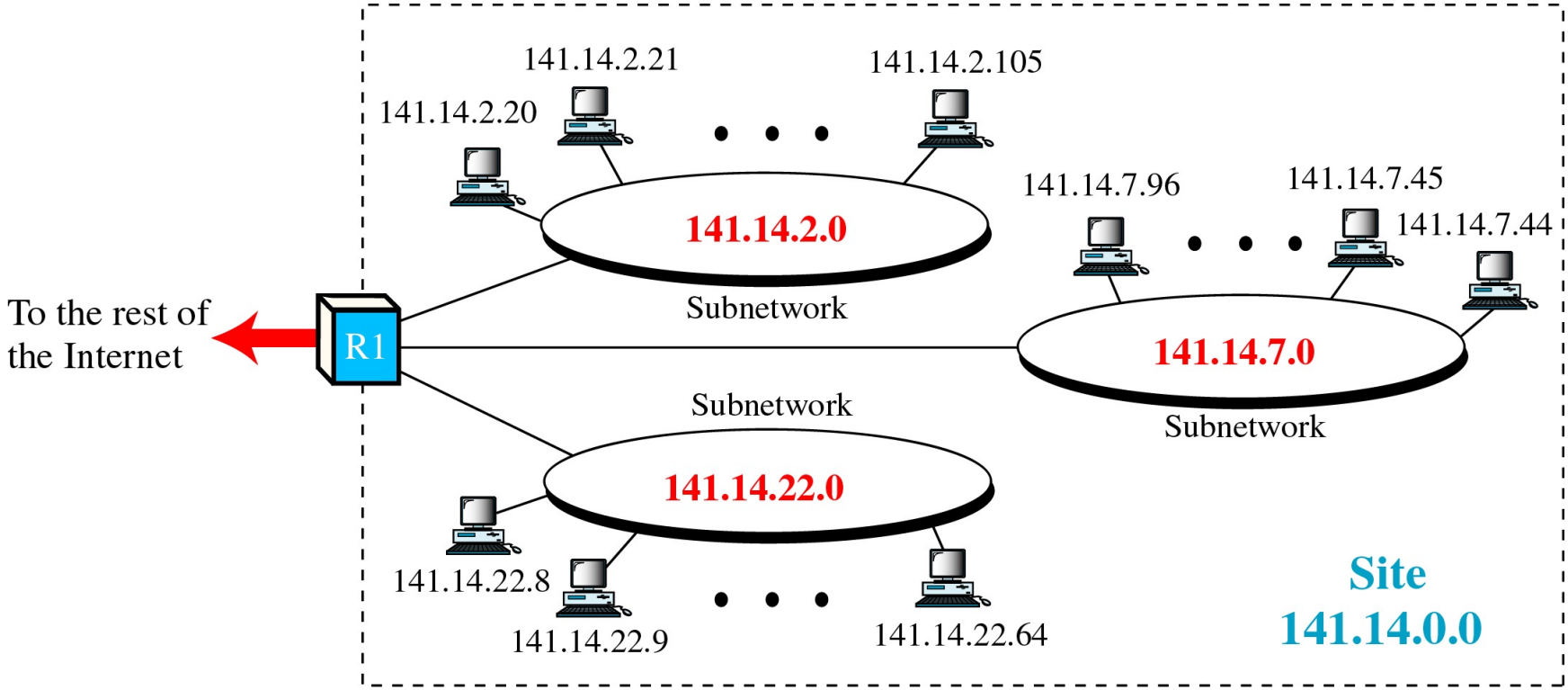
Without subnetting



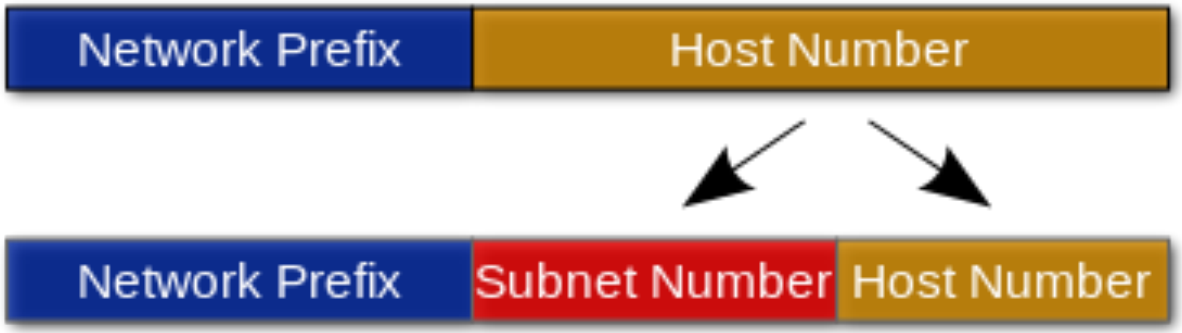
-Address assignment inefficiency;
-Cannot divide into group.

Subnetting

A Network with Three Levels of Hierarchy



How To Create Subnets

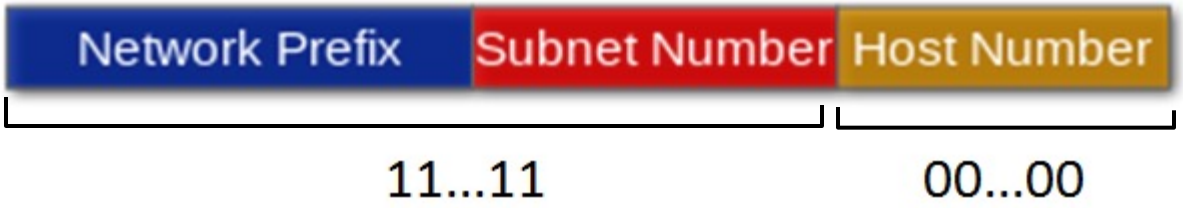


- Take bits from the host portion of the IP address and reserve to divide the subnet address.

How To Create Subnets

1. Determine the number of required subnets
2. Determine the number of required host per subnet
3. Based on above requirements:
   - Determine number of subnet bits
   - Assign subnet IDs to the network segments
   - Assign the range of valid host ID to hosts in each subnet.

Subnet Masks



- Used to define which part of the host address will be used as the subnet address.
- A 32-bit value that allows the recipient of IP packets to distinguish the network ID portion of the IP address from the host ID portion.

Default Subnet Masks

- Class A: 255.0.0.0
- Class B: 255.255.0.0
- Class C: 255.255.255.0

Number of Subnets:

$2^{\wedge}$# of subnet bits

Number of Valid Hosts:

$2^{\wedge}$# of host bits - 2

Class C 192 mask examples

Example:
Divide 192.168.1.0/24 into 4 subnets
Subnet Mask 11111111. 11111111. 11111111. 11000000

Subnet	Host	Meaning
00	000000 = 0	The network (do this first)
00	000001 = 1	The first valid host
00	111110 = 62	The last valid host
00	111111 = 63	The broadcast address (do this second)

Subnet	Host	Meaning
01	000000 = 64	The network
01	000001 = 65	The first valid host
01	111110 = 126	The last valid host
01	111111 = 127	The broadcast address

Class C 192 mask examples

Subnet	Host	Meaning
10	000000 = 128	The subnet address
10	000001 = 129	The first valid host
10	111110 = 190	The last valid host
10	111111 = 191	The broadcast address

Subnet	Host	Meaning
11	000000 = 192	The subnet address
11	000001 = 193	The first valid host
11	111110 = 254	The last valid host
11	111111 = 255	The broadcast address

Question

How many hosts and subnets are possible if you have an IP class B of 172.16.0.0/16 with a subnet mask of 255.255.254.0?

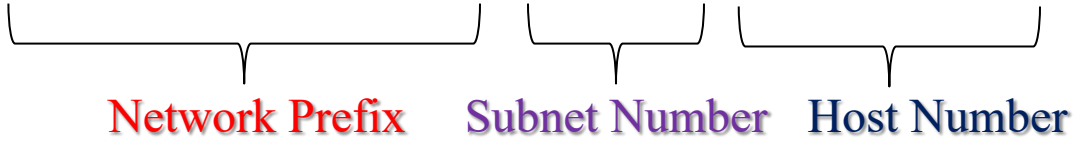
- A. 510 subnets and 126 hosts
- B. 512 subnets and 128 hosts
- C. 126 subnets and 512 hosts
- D. 128 subnets and 510 hosts

Answer

IP: 172.16.0.0/16

Subnet mask: 255.255.254.0

Subnet mask in binary 11111111.11111111.11111110. 00000000



Number of subnets $2^7 = 128$ subnets

Number of hosts for each subnet: $2^9 - 2 = 510$ hosts

- Answer: D

Answer

Subnets Example

```
Netmask:   255.255.254.0 = 23    11111111.11111111.1111111 0.00000000
Wildcard:  0.0.1.255             00000000.00000000.0000000 1.11111111

Network:   172.16.0.0/23         10101100.00010000.0000000 0.00000000 (Class B)
Broadcast: 172.16.1.255          10101100.00010000.0000000 1.11111111
HostMin:   172.16.0.1            10101100.00010000.0000000 0.00000001
HostMax:   172.16.1.254          10101100.00010000.0000000 1.11111110
Hosts/Net: 510                   (Private Internet)

Network:   172.16.2.0/23         10101100.00010000.0000001 0.00000000 (Class B)
Broadcast: 172.16.3.255          10101100.00010000.0000001 1.11111111
HostMin:   172.16.2.1            10101100.00010000.0000001 0.00000001
HostMax:   172.16.3.254          10101100.00010000.0000001 1.11111110
Hosts/Net: 510                   (Private Internet)

Network:   172.16.4.0/23         10101100.00010000.0000010 0.00000000 (Class B)
Broadcast: 172.16.5.255          10101100.00010000.0000010 1.11111111
HostMin:   172.16.4.1            10101100.00010000.0000010 0.00000001
HostMax:   172.16.5.254          10101100.00010000.0000010 1.11111110
Hosts/Net: 510                   (Private Internet)

Network:   172.16.6.0/23         10101100.00010000.0000011 0.00000000 (Class B)
Broadcast: 172.16.7.255          10101100.00010000.0000011 1.11111111
HostMin:   172.16.6.1            10101100.00010000.0000011 0.00000001
HostMax:   172.16.7.254          10101100.00010000.0000011 1.11111110
Hosts/Net: 510                   (Private Internet)
```

Quiz

P1) If a host on a network has the address 172.16.45.16/30. What is the address of the su bnetwork to which this host belongs ?

P2) Find the total # addresses wasted given the following information:

Network	Hosts needed	IP address
London	20	192.168.12.0/27
Paris	50	192.168.13.0/26
Madrid	14	192.168.14.0/28
Hamburg	6	192.168.12.32/29

Quiz - answer

1) 172.16.45.16/30

The last octet in binary form is

$$16_{10} = \underbrace{0000111}_{\text{belong to the subnet mask}}0_2.$$

Only 6 bits of this octet belong to the subnet mask.

Hence, the sub-network is

172.16.45.00001100

172.16.45.12

2) 10+12+0+0 = 22

Quiz - answer

2)

Network	Hosts needed	IP address
London	20	192.168.12.0/27
Paris	50	192.168.13.0/26
Madrid	14	192.168.14.0/28
Hamburg	6	192.168.12.32/29

1 Network Address
1 Broadcast Address

Maximum Number of hosts:

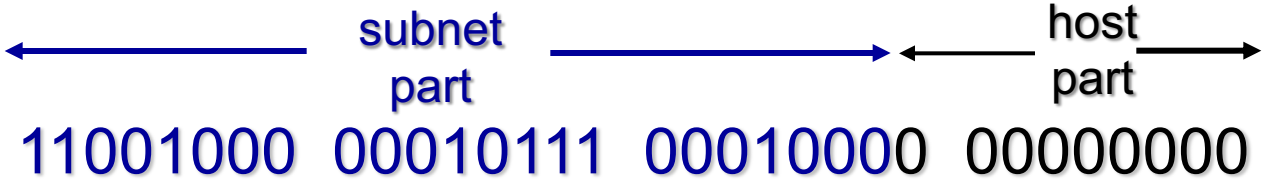
- London: $2^{(32-27)} - 2 = 30$
- Paris: $2^{(32-26)} - 2 = 62$
- Madrid: $2^{(32-28)} - 2 = 14$
- Hamburg: $2^{(32-29)} - 2 = 6$

Answer: 30 – 20 + 62 – 50 + 14 – 14 + 6 – 6 = 22 wasted hosts

Classless Inter-Domain Routing (RFC 1519)

CIDR: Classless InterDomain Routing

- subnet portion of address of arbitrary length
- address format: a.b.c.d/x, where x is # bits in subnet portion of address



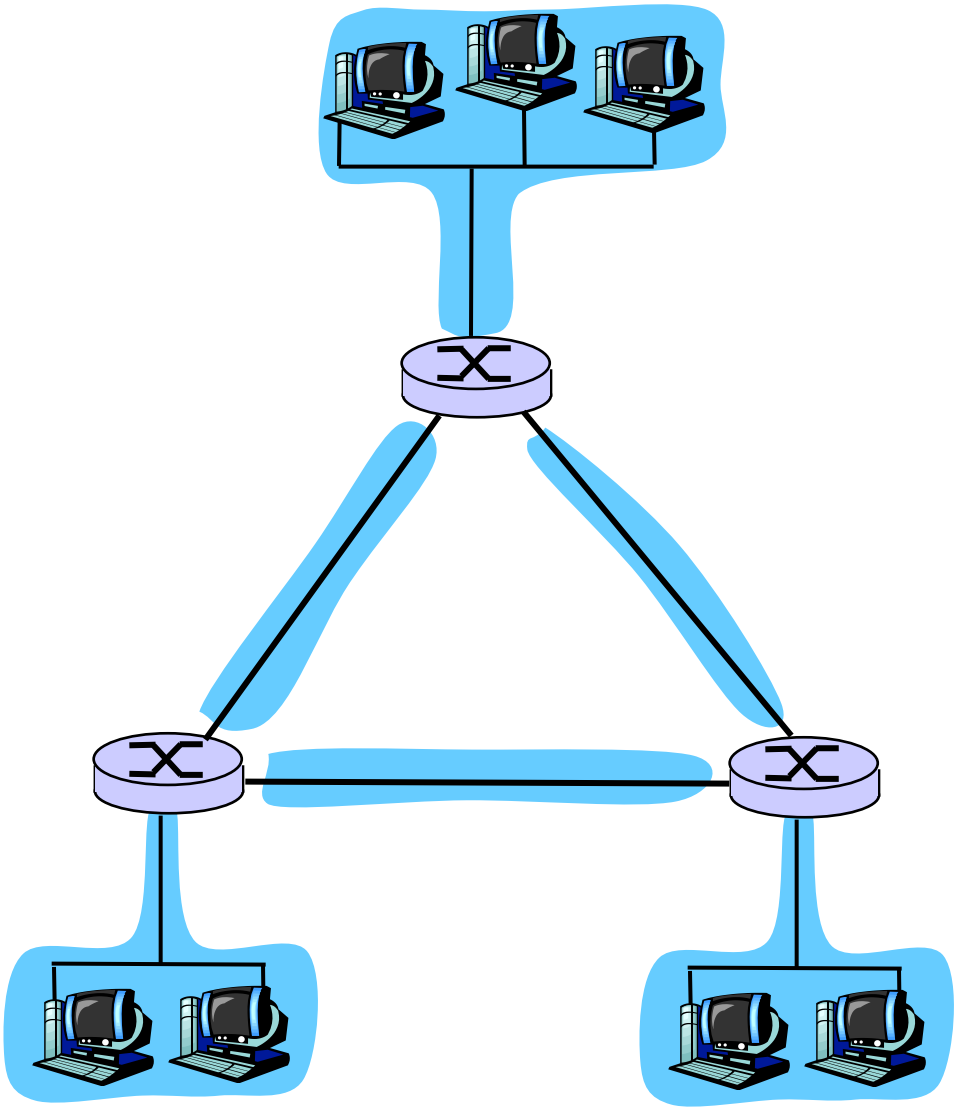
200.23.16.0/23

CIDR – Variable length subnet mask (VLSM)

Given IP range 192.168. 0.0/24.

Each LAN requires 60 valid host IPs.

Design IP addresses for this network ?

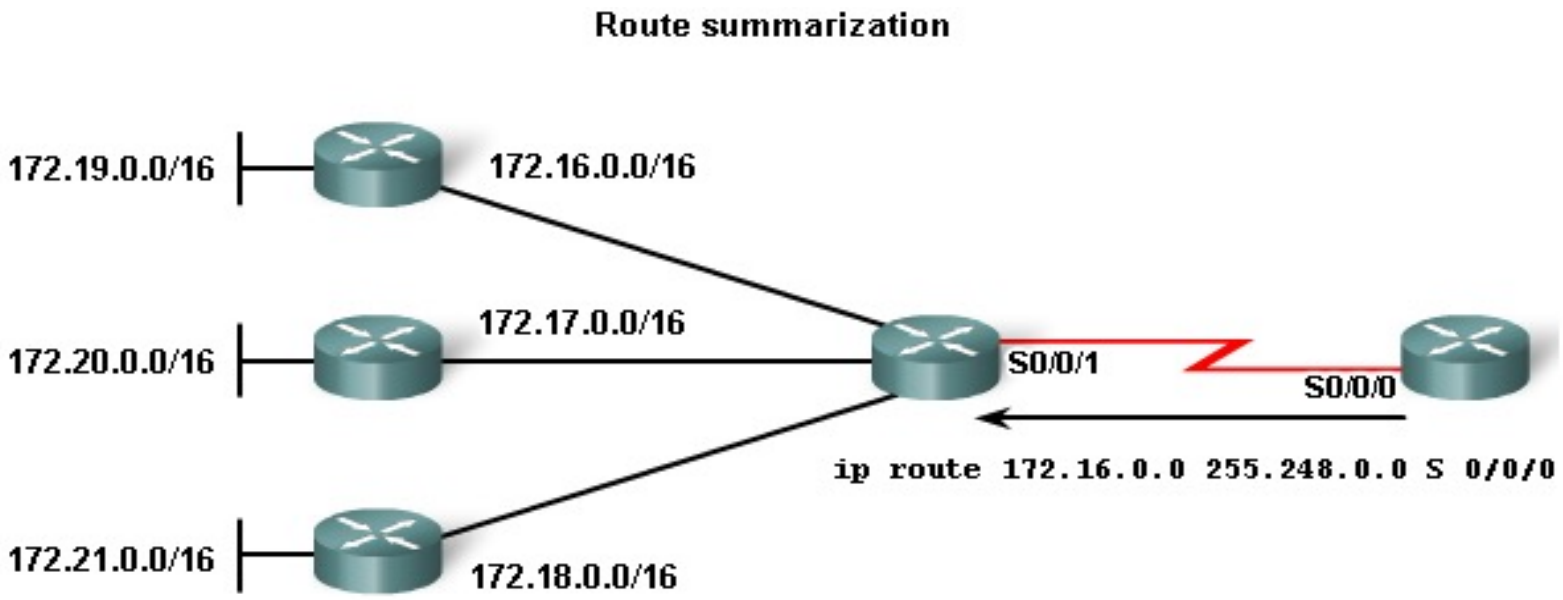


Read more:
https://www.geeksforgeeks.org/introduction-of-variable-length-subnet-mask-vlsm/

CIDR – route aggregation

- When the number of network stated growing exponentially, routing table size started exploding.
- In order to reducing table size, CIDR propose a "rational geographical-based distribution" of IP addresses to be able to summarize routes and uses masks instead of classes.
- E.g., 200.1.10.0/24 and 200.1.10.1/24
  → 200.1.10.0/23

Route aggregation



Route aggregation – example 1

- Aggregate the following subnets:
  - 203.162.1.0/30
  - 203.162.1.4/30
  - 203.162.1.8/30
  - 203.162.1.12/30

how many bits these network addresses have in common?

Decimal	Binary
0	00000000
4	00000100
8	00001000
12	00001100

The first 4 bits of the 4th octet are the same. Now we have enough information to create our summary address. 8 + 8 + 8 + 4 = 28 bits

Our summary address will be 203.162.1.0 /28 (subnet mask 255.255.255.240).

Route aggregation – example 2

- What is the best summary for the following range of subnets?

  172.20.32.0/24 to 172.20.47.0/24

  Answer: 172.20.32.0/20 or 172.20.32.0 255.255.240.0

Decimal	Binary
32	00100000
47	00101111

The first 4 bits of the 3rd octet are the same. Now we have enough information to create our summary address. 8 + 8 + 4 = 20 bits
Our summary address will be 172.20.32.0/20 (subnet mask 255.255.240.0).

IP addresses: how to get one?

Q: How does *host* get IP address?

- hard-coded by system admin in a file
  - Windows: control-panel->network->configuration->tcp/ip->properties
  - Linux/Unix:
    - /etc/rc.config
    - /etc/sysconfig/network-scripts/ifcfg-ethx
    - ifconfig
- DHCP: Dynamic Host Configuration Protocol: dynamically get address from as server
  - "plug-and-play"

IP addresses: how to get one?

The ISP has been allocated the address block 200.23.16.0/20. The ISP, in turn, could divide its address block into eight equal-sized contiguous address blocks and give one of these address blocks out to each of up to eight organizations that are supported by this ISP.

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

Summary

- IP address structure
- IP address classes
- IP subnetting technique
- CIDR