PART IV

CLASSFUL INTERNET ADDRESSES

Definitions

- Name
  - Identifies *what* an entity is
  - Often textual (e.g., ASCII)
- Address
  - Identifies *where* an entity is located
  - Often binary and usually compact
  - Sometimes called locator
- Route
  - Identifies *how* to get to the object
  - May be distributed

Internet Protocol Address (IP Address)

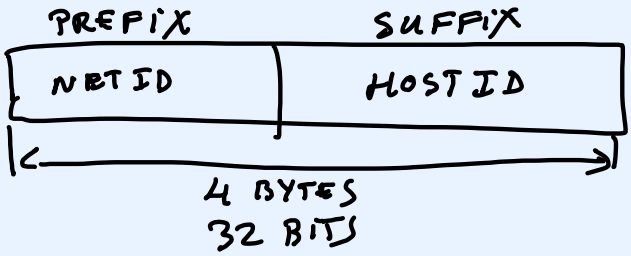
- Analogous to hardware address
- Unique value assigned as unicast address to each host on Internet
- Used by Internet applications

IP Address Details

- 32-bit binary value IPv4
- Unique value assigned to each host in Internet
- Values chosen to make routing efficient

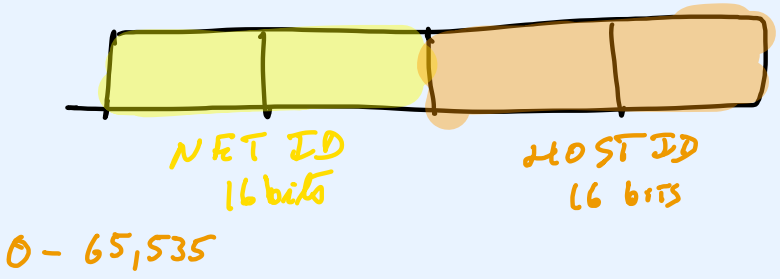
IP Address Division

- Address divided into two parts
  - Prefix (network ID) identifies network to which host attaches
  - Suffix (host ID) identifies host on that network



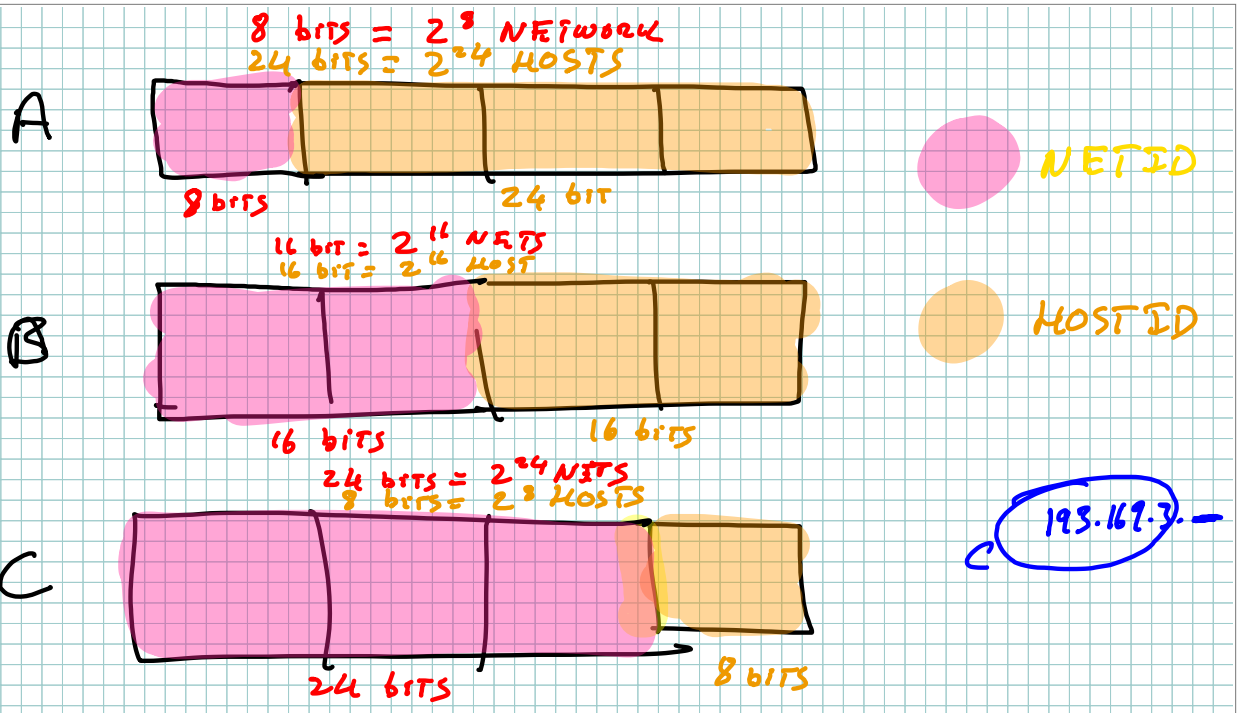
Classful Addressing

- Original IP scheme
- Explains many design decisions
- New schemes are backward compatible



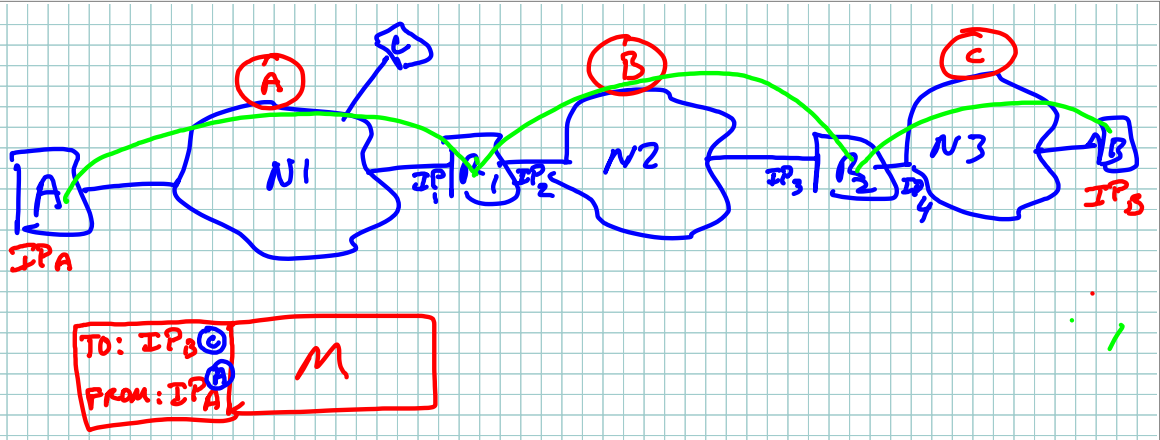
Desirable Properties Of An Internet Addressing Scheme

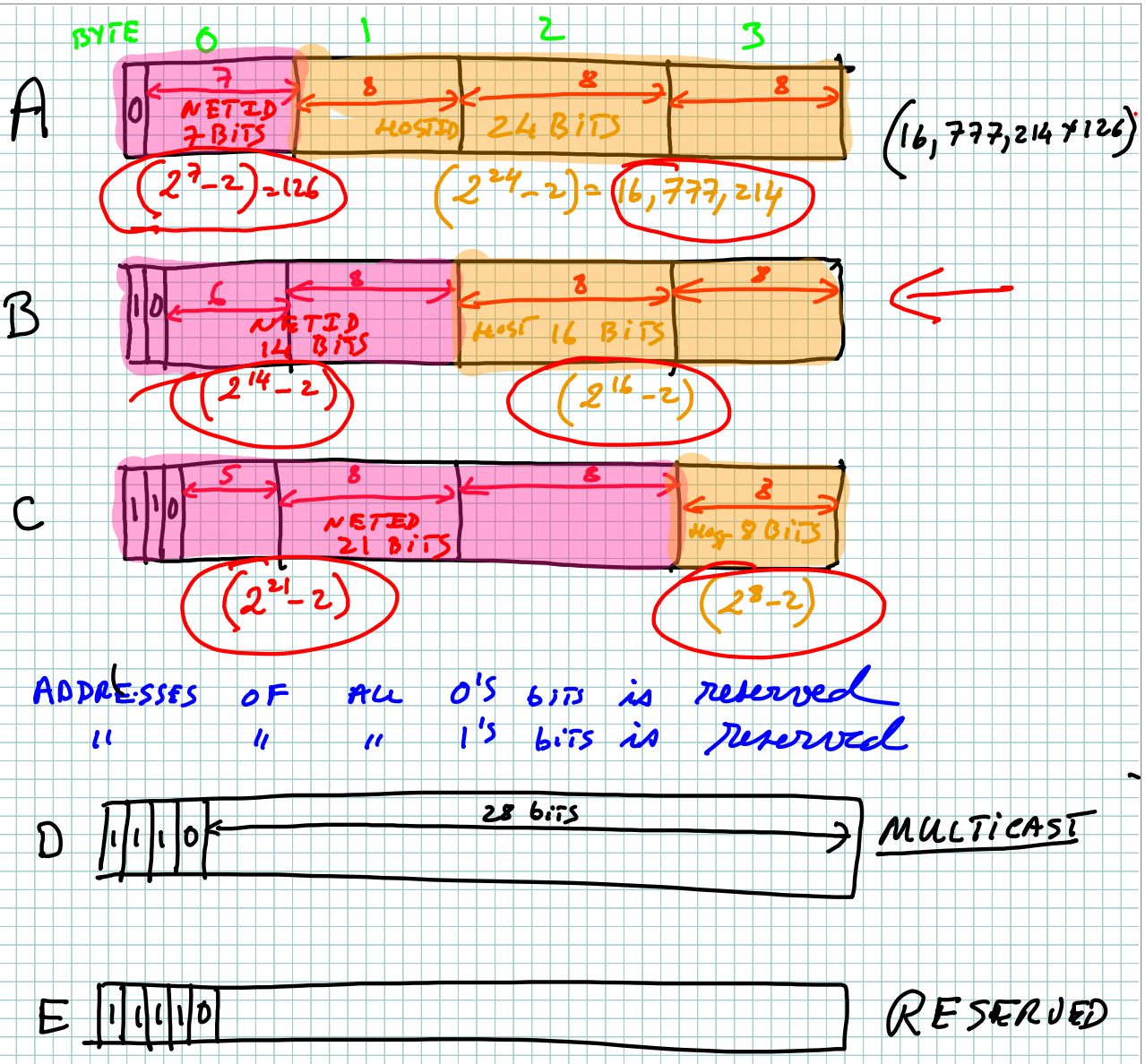
- Compact (as small as possible)
- Universal (big enough)
- Works with all network hardware
- Supports efficient decision making
  - Test whether a destination can be reached directly
  - Decide which router to use for indirect delivery
  - Choose next router along a path to the destination



B 128.10.—.—
129.15.—.—

A 9.—.—.—
13.—.—.—


A
N1
B
N2
C
N3
A
IP_A
IP_1
IP_2
IP_3
IP_4
IP_B
TO: IP_B
FROM: IP_A
M


BYTE 0 1 2 3
A
0
7
NETID
7 BITS
8
HOSTID
8
24 BITS
8
$(2^7-2)=126$
$(2^{24}-2)=16,777,214$
$(16,777,214 \times 126)$
B
10
6
8
NETID
14 BITS
8
HOST 16 BITS
8
$(2^{14}-2)$
$(2^{16}-2)$
C
110
5
8
NETID
21 BITS
8
8
HOST 8 BITS
$(2^{21}-2)$
(2^8-2)
ADDRESSES OF ALL 0'S BITS is reserved
" " " 1's bits is Reserved
D
1110
28 bits
MULTICAST
E
11110
RESERVED

7B 3E 49 7F

A — 0 111 1011

7B = 123

3E = 62

49 = 73

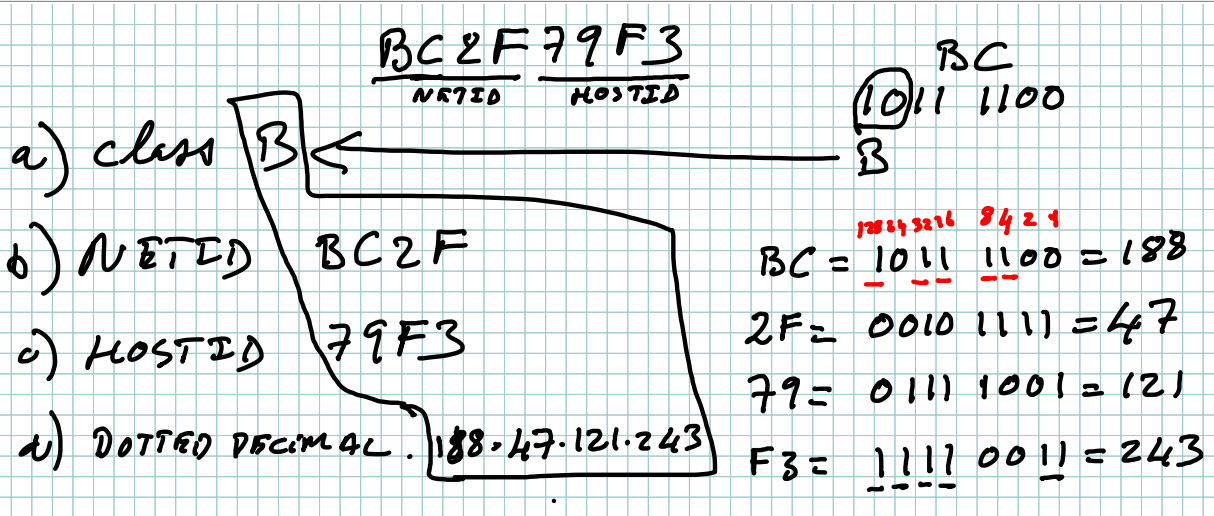
7F = 127

a) CLASS : A

b) NETID : 7B

c) HOSTID : 3E497F

d) DOTTED DECIMAL: 123.62.73.127


BC2F79F3
NETID
HOSTID
a) class B
b) NETID BC2F
c) HOSTID 79F3
d) DOTTED DECIMAL. 188.47.121.243
BC
10 11 1100
B
BC = 10 11 11 00 = 188
2F = 0010 1111 = 47
79 = 0111 1001 = 121
F3 = 1111 00 11 = 243

C9B3FDE9

a) class: C

b) NETID: C9B3FD

c) HOSTID: E9

d) dotted decimal: 201.179.253.233

C9
1100 1001

C9 = 1100 1001 = 201
B3 = 1011 0011 = 179
FD = 1111 1101 = 253
E9 = 1110 1001 = 233

9DB37FE2

a) B

b) 9DB3

c) 7FE2

d) 157.179.127.226

9D
B (1)001 1101

9D = 1001 1101 = 157

B3 = 1011 0011 = 179

7F = 0111 1111 = 127

E2 = 1110 0010 = 226

56 B1 3E D4

a) A

b) 56

c) B13ED4

d) 86.177.62.212

56

0101 0110

56 = 0101 0110 = 86

B1 = 1011 0001 = 177

3E = 0011 1110 = 62

D4 = 1101 0100 = 212

D14FD2EC

D7

1101 0001

a) C

b) D14FD2

c) EC

d) 209.79.214.236

D1 = 1101 0001 = 209

4F = 0100 1111 = 79

D2 = 1101 0010 = 214

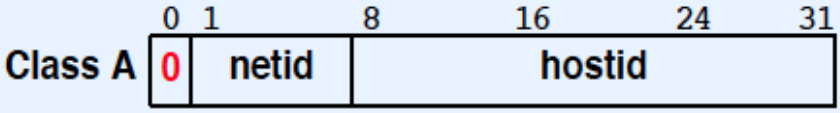
EC = 1110 1100 = 236

Division Of Internet Address Into Prefix And Suffix

- How should division be made?
  - Large prefix, small suffix means many possible networks, but each is limited in size
  - Large suffix, small prefix means each network can be large, but there can only be a few networks
- Original Internet address scheme designed to accommodate both possibilities
  - Known as *classful* addressing

Original IPv4 Address Classes

Three Principle Classes



Class A Addresses are used for the handful of networks that have more than 2^{16} (i.e. more than 65,536) hosts.

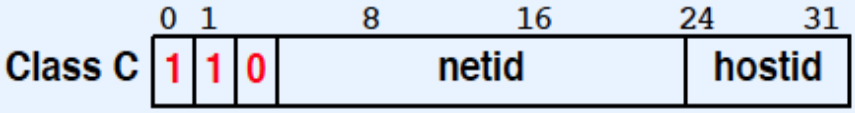
- 7 Bits for netid
- 24 Bits for hostid

Class B Addresses are used for intermediate size networks that have up to 2^{16} (i.e. up to 65,536) hosts.

- 14 Bits for netid
- 16 Bits for hostid

Original IPv4 Address Classes

Three Principle Classes

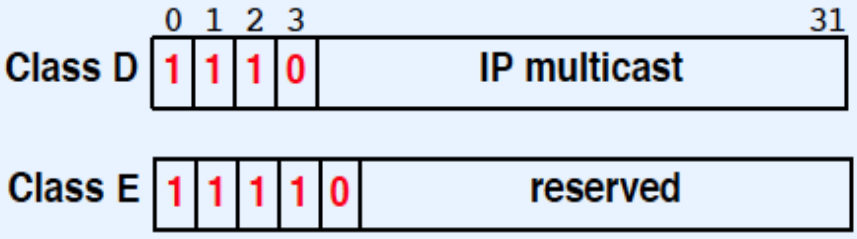


Class C Addresses are used for networks that have less than 2^8 (i.e. less than 256) hosts.

- 21 Bits for netid
- 8 Bits for hostid

Original IPv4 Address Classes

Other (seldom used) Classes



Important Property

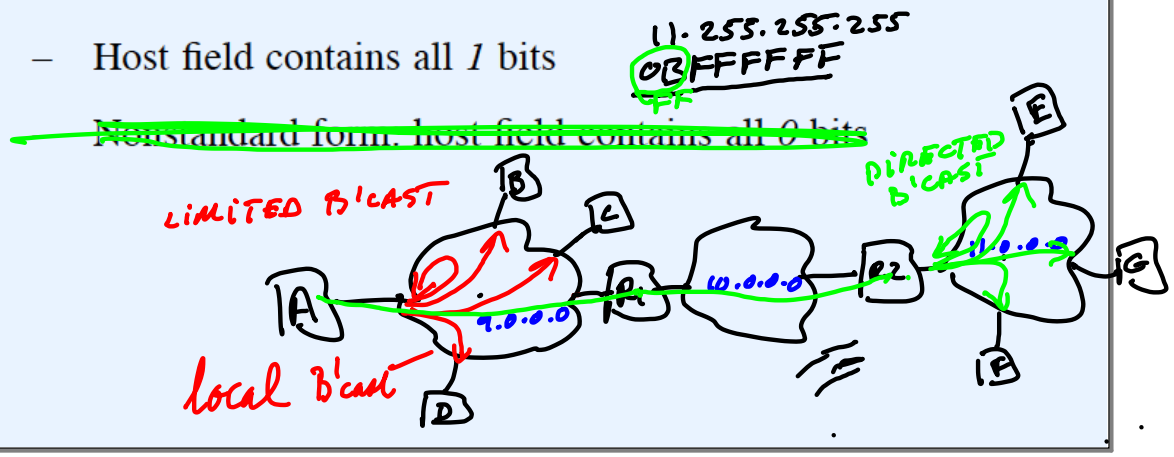
- Classful addresses are *self-identifying*
- Consequences
  - Can determine boundary between prefix and suffix from the address itself
  - No additional state needed to store boundary information
  - Both hosts and routers benefit

Endpoint Identification

Because IP addresses encode both a network and a host on that network, they do not specify an individual computer, but a connection to a network.

IP Address Conventions

- When used to refer to a network
  - Host field contains all *0* bits
- Broadcast on the local wire
  - Network and host fields both contain all *1* bits
- Directed broadcast: broadcast on specific (possibly remote) network
  - Host field contains all *1* bits
  - ~~Nonstandard form: host field contains all 0 bits~~



Assignment Of IP Addresses

- All hosts on same network assigned same address prefix
  - Prefixes assigned by central authority
  - Obtained from ISP
- Each host on a network has a unique suffix
  - Assigned locally
  - Local administrator must ensure uniqueness

0 000 1010

Advantages Of Classful Addressing

- Computationally efficient
  - First bits specify size of prefix / suffix
- Allows mixtures of large and small networks

Directed Broadcast

IP addresses can be used to specify a directed broadcast in which a packet is sent to all computers on a network; such addresses map to hardware broadcast, if available. By convention, a directed broadcast address has a valid netid and has a hostid with all bits set to 1.

Limited Broadcast

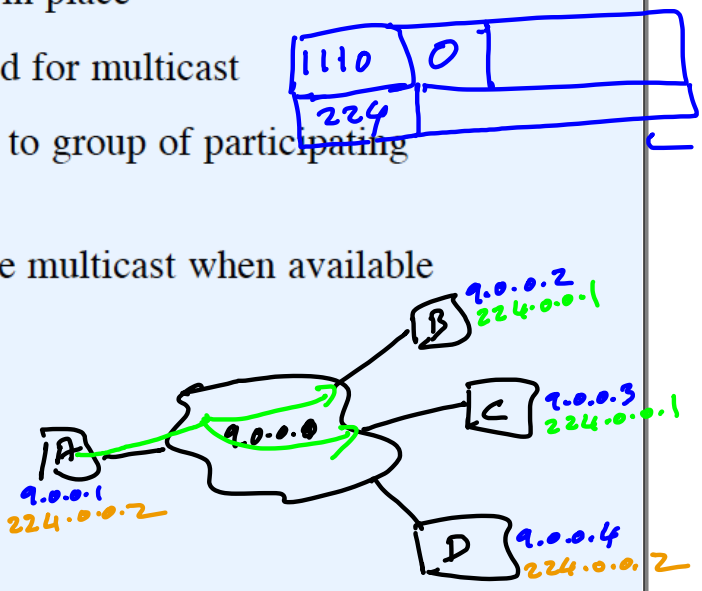
- All 1's
- Broadcast limited to local network only (no forwarding)
- Useful for bootstrapping

All Zeros IP Address

- Can only appear as source address
- Used during bootstrap before computer knows its address
- Means ‘‘this’’ computer

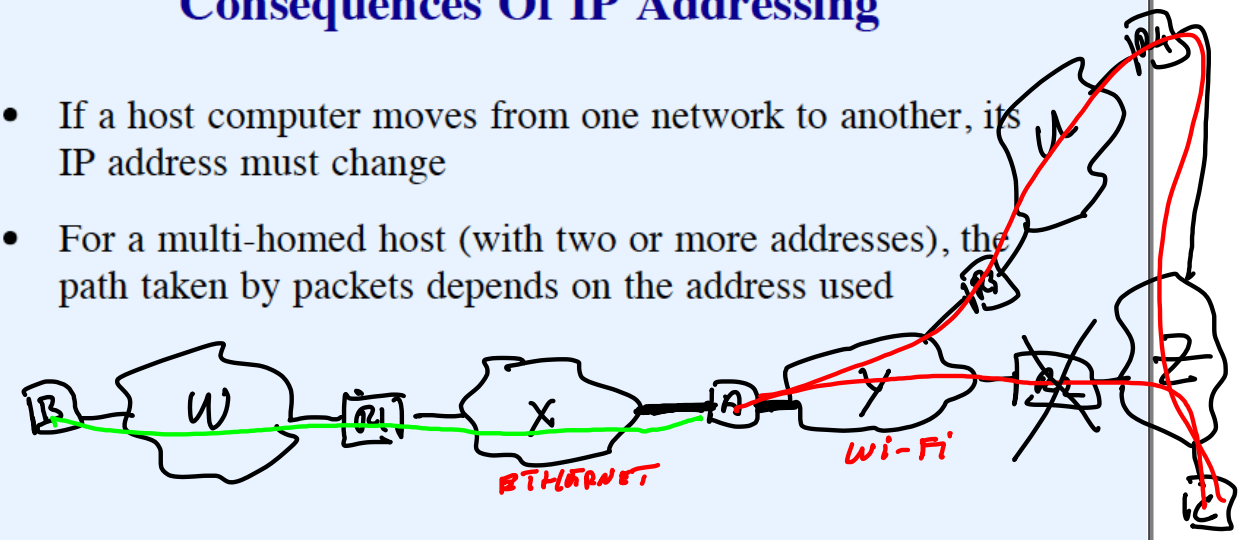
Internet Multicast

- IP allows Internet multicast, but no Internet-wide multicast delivery system currently in place
- Class D addresses reserved for multicast
- Each address corresponds to group of participating computers
- IP multicast uses hardware multicast when available
- More later in the course

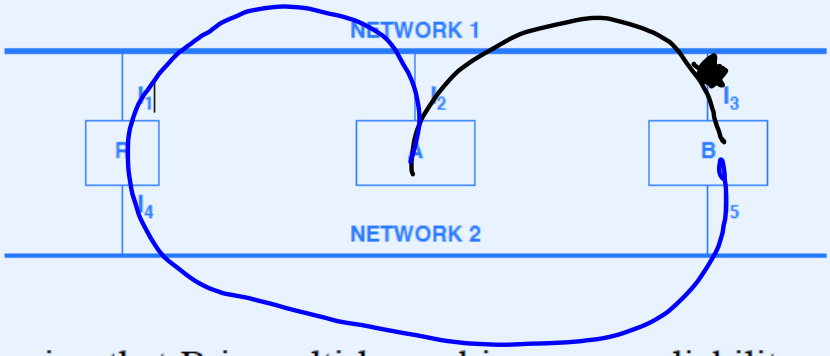


Consequences Of IP Addressing

- If a host computer moves from one network to another, its IP address must change
- For a multi-homed host (with two or more addresses), the path taken by packets depends on the address used



Multi-Homed Hosts And Reliability



- Knowing that B is multi-homed increases reliability
- If interface I_3 is down, host A can send to the interface I_5

Dotted Decimal Notation

- Syntactic form for expressing 32-bit address
- Used throughout the Internet and associated literature
- Represents each octet in decimal separated by periods (dots)

Example Of Dotted Decimal Notation

- A 32-bit number in binary

  10000000 00001010 00000010 00000011

- The same 32-bit number expressed in dotted decimal notation

  128.10.2.3

Loopback Address

- Used for testing
- Refers to local computer (never sent to Internet)
- Address is 127.0.0.1

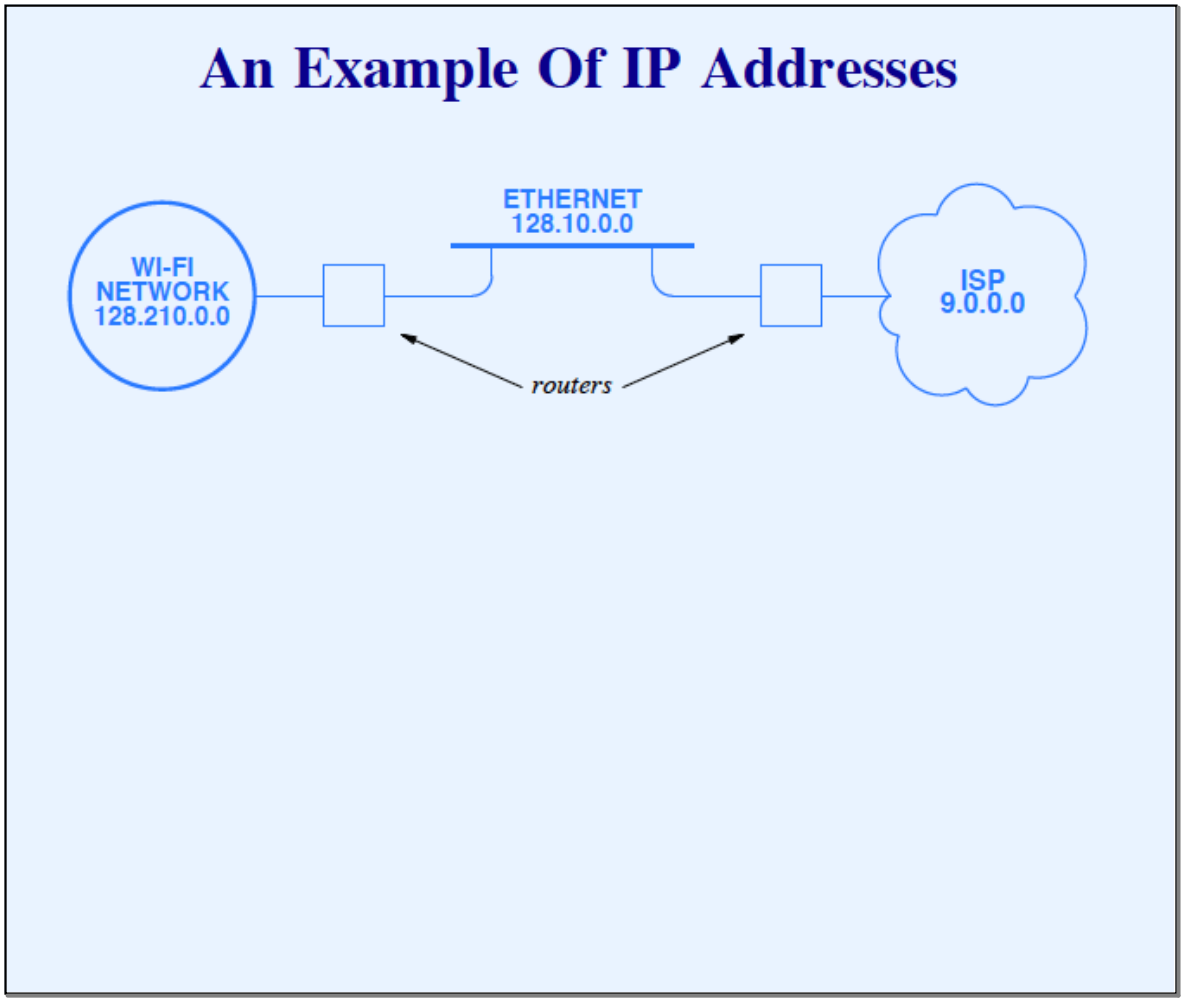
Classful Address Ranges

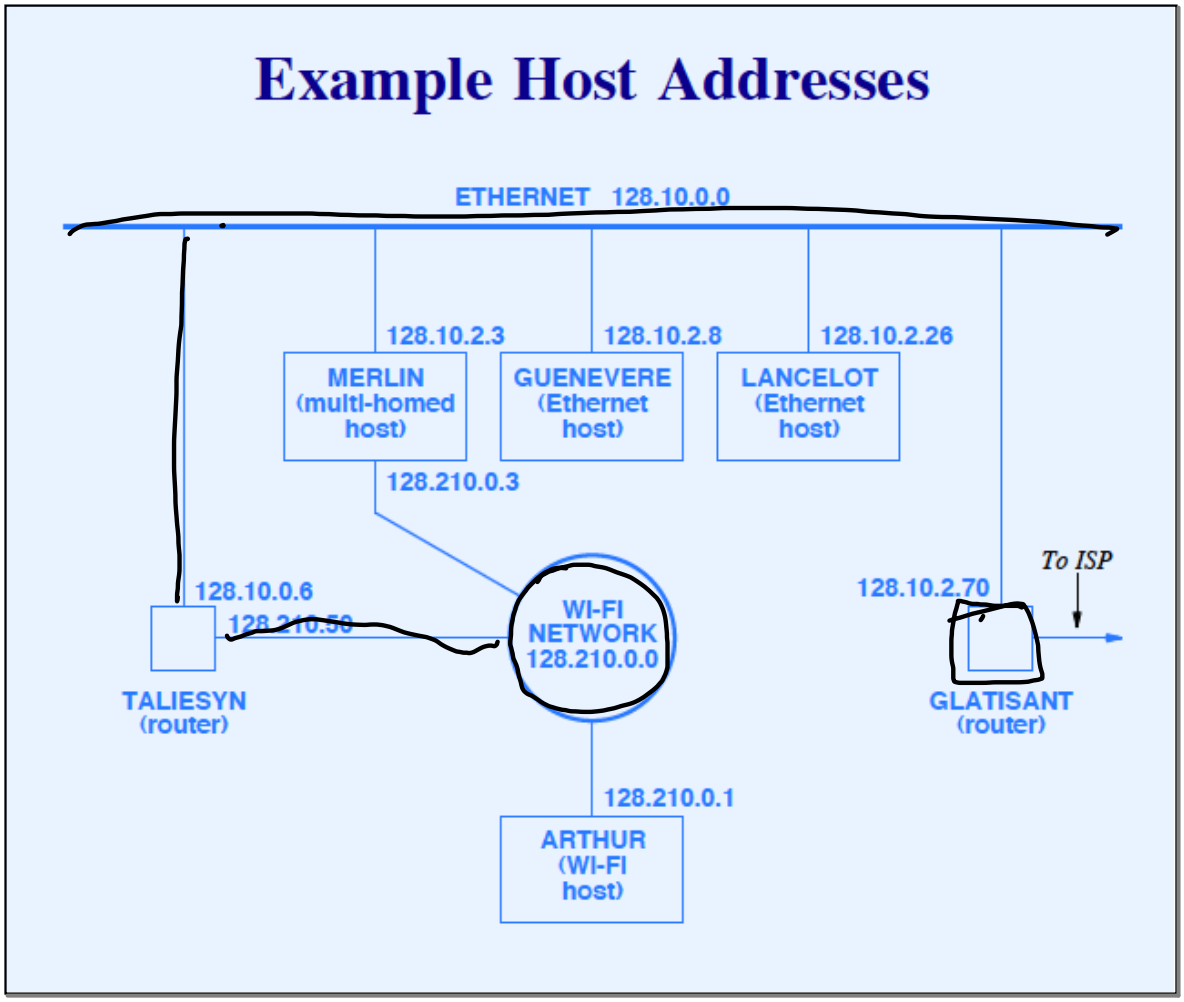
Class	Lowest Address	Highest Address
A	1.0.0.0	126.0.0.0
B	128.1.0.0	191.255.0.0
C	192.0.1.0	223.255.255.0
D	224.0.0.0	239.255.255.255
E	240.0.0.0	255.255.255.254

Summary Of Address Conventions

all 0s		This host [1]
all 0s	host	Host on this net [1]
all 1s		Limited broadcast (local net) [2]
net	all 1s	Directed broadcast for net [2]
127	anything (often 1)	Loopback [3]

Notes: [1] Allowed only at system startup and is never a valid destination address.
[2] Never a valid source address.
[3] Should never appear on a network.


An Example Of IP Addresses
ETHERNET
128.10.0.0
WI-FI
NETWORK
128.210.0.0
ISP
9.0.0.0
routers


Example Host Addresses
ETHERNET 128.10.0.0
128.10.2.3
128.10.2.8
128.10.2.26
MERLIN
(multi-homed
host)
GUENEVERE
(Ethernet
host)
LANCELOT
(Ethernet
host)
128.210.0.3
To ISP
128.10.0.6
128.10.2.70
WI-FI
NETWORK
128.210.0.0
TALIESYN
(router)
GLATISANT
(router)
128.210.0.1
ARTHUR
(WI-FI
host)

Another Addressing Example

- Assume an organization has three networks
- Organization obtains three prefixes, one per network
- Host address must begin with network prefix

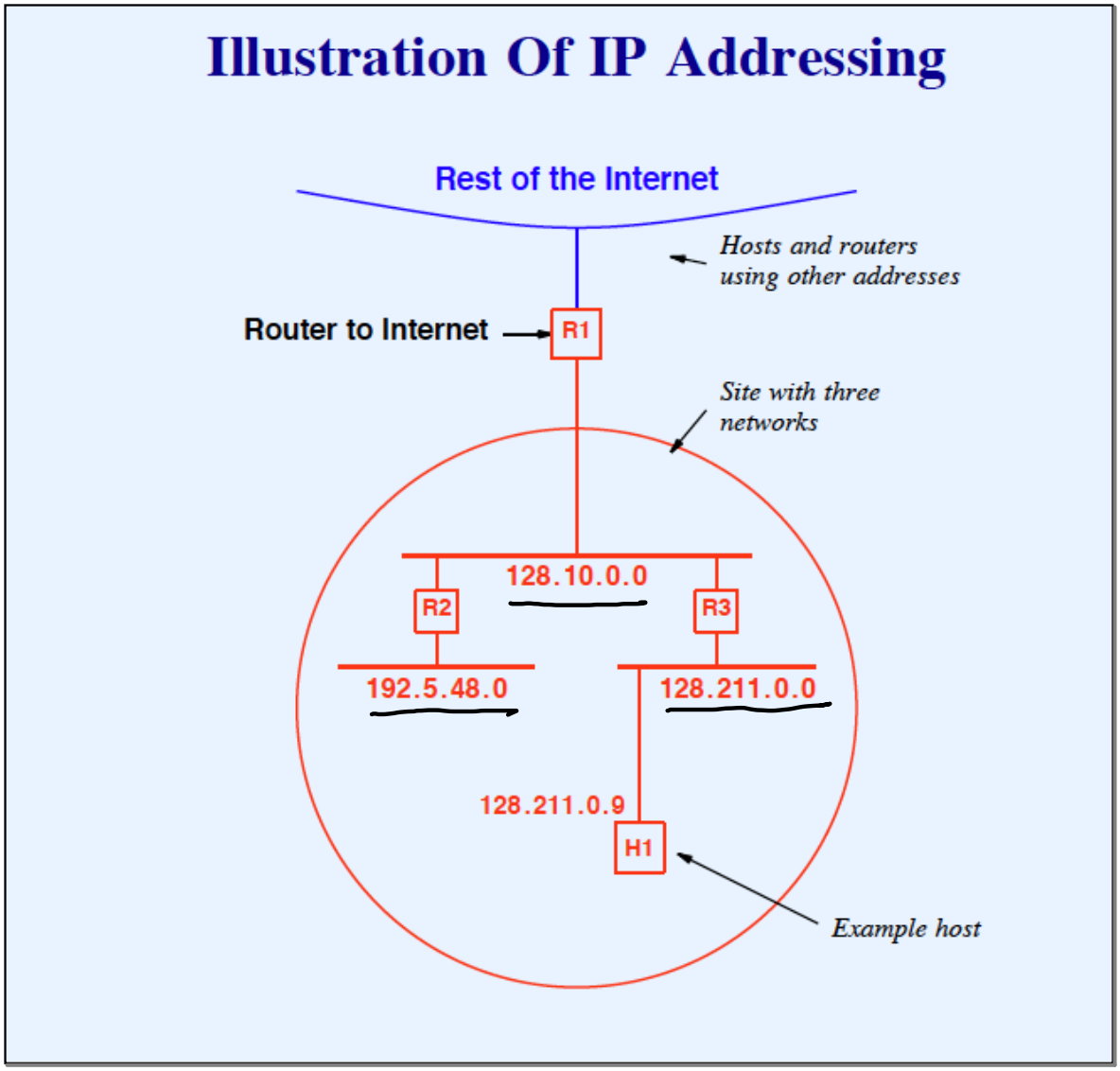


Illustration Of IP Addressing
Rest of the Internet
Hosts and routers using other addresses
Router to Internet
R1
Site with three networks
128.10.0.0
R2
R3
192.5.48.0
128.211.0.0
128.211.0.9
H1
Example host

Summary

- IP address
  - 32 bits long
  - Prefix identifies network
  - Suffix identifies host
- Classful addressing uses first few bits of address to determine boundary between prefix and suffix

Summary
(continued)

- Special forms of addresses handle
  - Limited broadcast
  - Directed broadcast
  - Network identification
  - This host
  - Loopback