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)

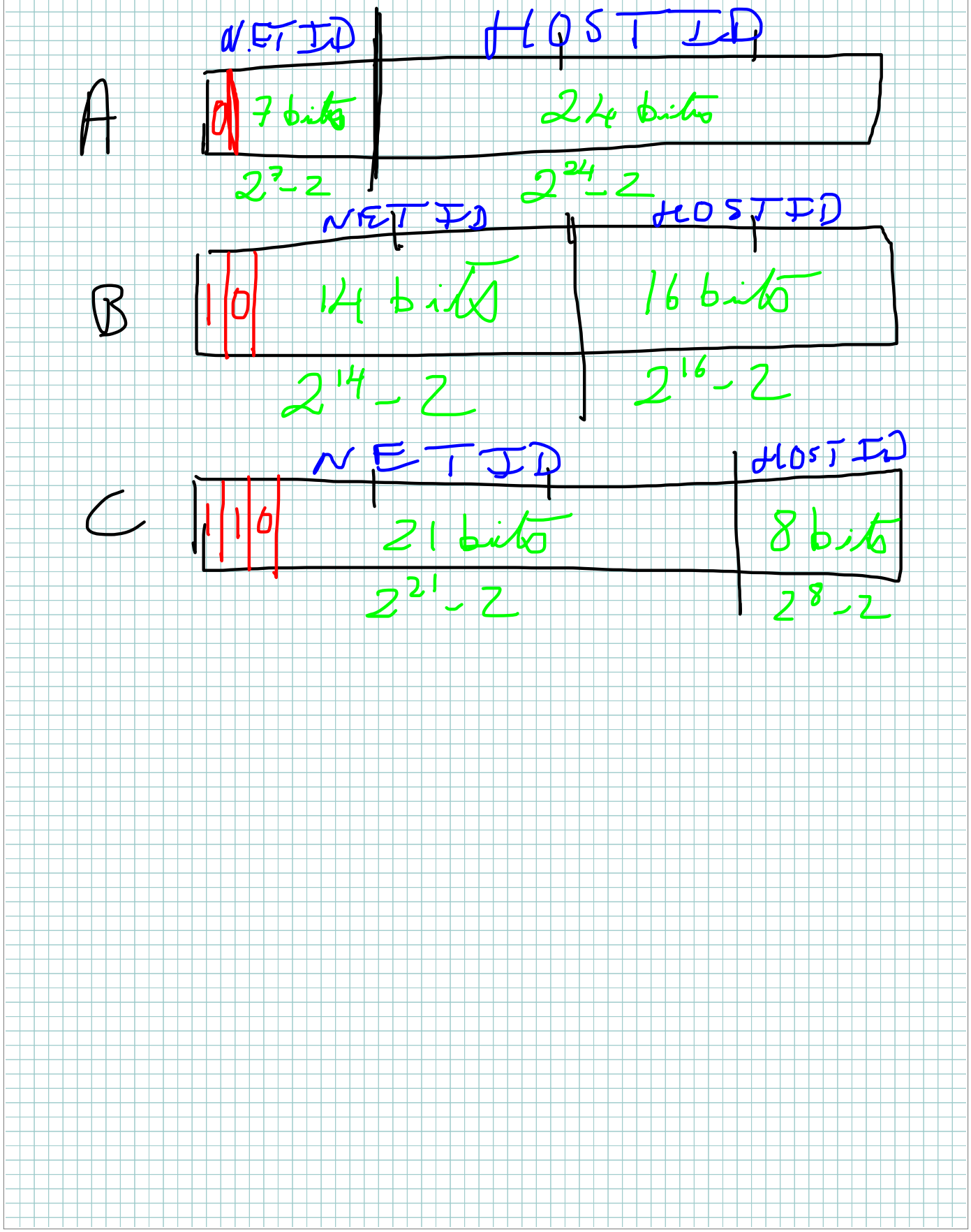
- Analogous to hardware address
- Unique value assigned as unicast address to each host on Internet
- Used by Internet applications

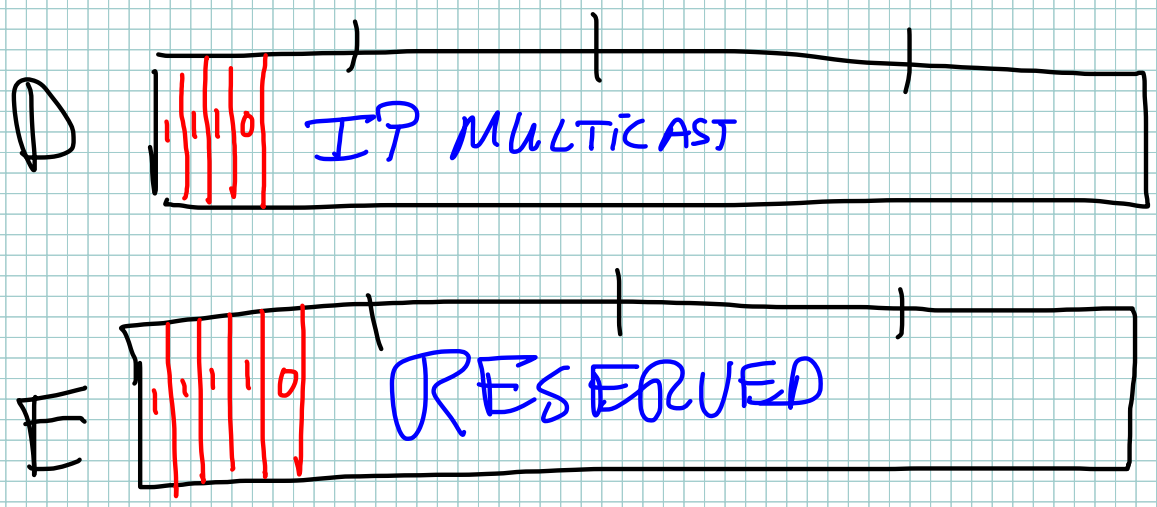
IP Address Details

- 32-bit binary value
- 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


A
NET ID
HOST ID
0
7 bits
24 bits
2^7-2
$2^{24}-2$
B
NET ID
HOST ID
1 0
14 bits
16 bits
$2^{14}-2$
$2^{16}-2$
C
NET ID
HOST ID
1 1 0
21 bits
8 bits
$2^{21}-2$
2^8-2


D
1 1 1 0
IP MULTICAST
E
1 1 1 1 0
RESERVED

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

A32D7E4C

A3 = 1010 0011

B

NETID = A32D

HOSTID = 7E4C

DOTTED DECIMAL: 163.45.126.76

$(16^1 \times A) + (16^0 \times 3)$

$(16 \times 10) + 3 = 163$

$(16^1 \times 2) + (16^0 \times D)$

$(16 \times 2) + (1 \times 13)$

32 + 45

$(16^1 \times 7) + (16^0 \times E)$

112 + 14

126

$(16 \times 4) + (1 \times 12)$

64 + 12

NETWORK A32D0000

163.45.0.0

74 3C 2D 1E

74 = 0111 0100

A

NETID = 74

HOSTID = 3C 2D 1E

(16x7) + (4) = 116

(16x3) + (2) = 60

(16x2) + (13) = 45

(16x1) + 14 = 30

D.D : 116.60.45.30

NETWORK 74000000

116.0.0.0

D32E4C35

D3 = 1101 0011

C

NETID: D32E4C

HOSTID: 35

D.D: 211.46.76.53

NETWORK

D32E4C

211.46.76.0

(16 x 13) + 3 = 208 + 3 = 211

(16 x 2) + 14 = 32 + 14 = 46

(16 x 4) + (12)

64 + 12 = 76

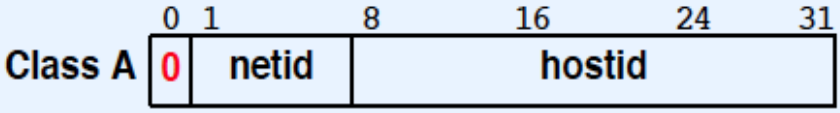
(16 x 3) + 5 = 53

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

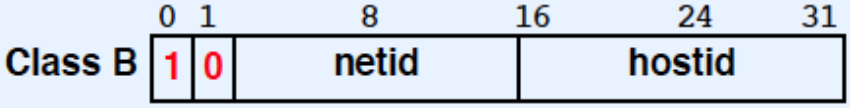
Original IPv4 Address Classes

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

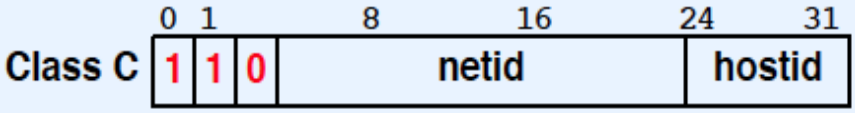


Class B Addresses are used for intermediate size networks that have up to 2^{16} (i.e. up to 65,536) hosts.

- 14 Bits for netid
- 16 Bits for hostid

Original IPv4 Address Classes

Three Principle Classes

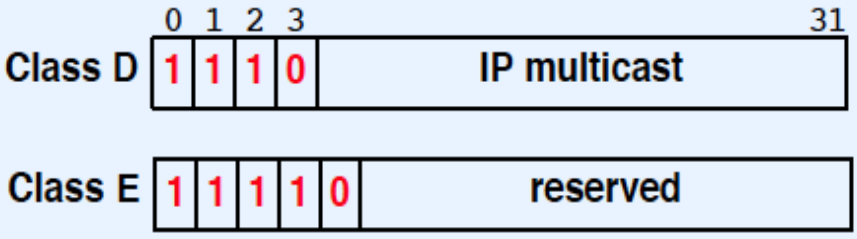


Class C Addresses are used for networks that have less than 2^8 (i.e. less than 256) hosts.

- 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

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

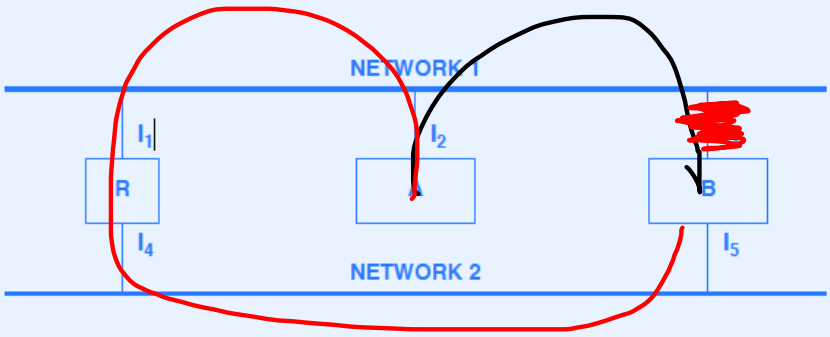
Internet Multicast

- 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

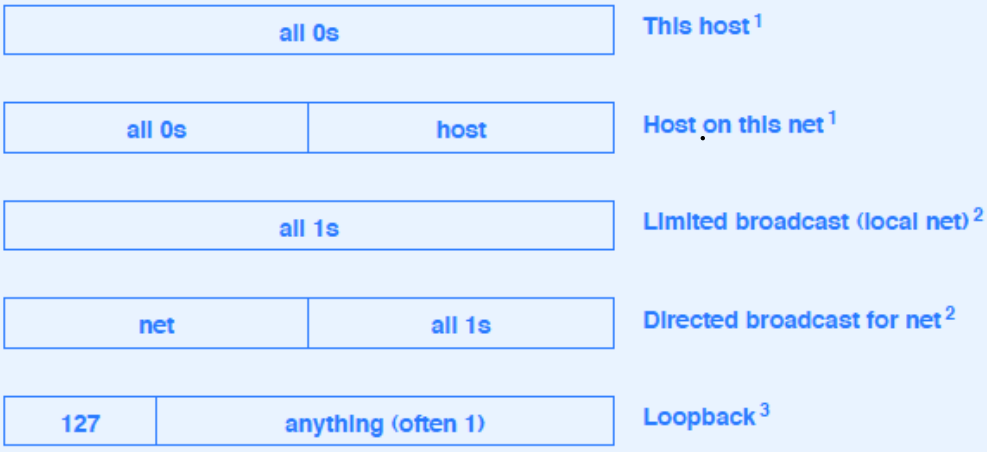
Loopback Address

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

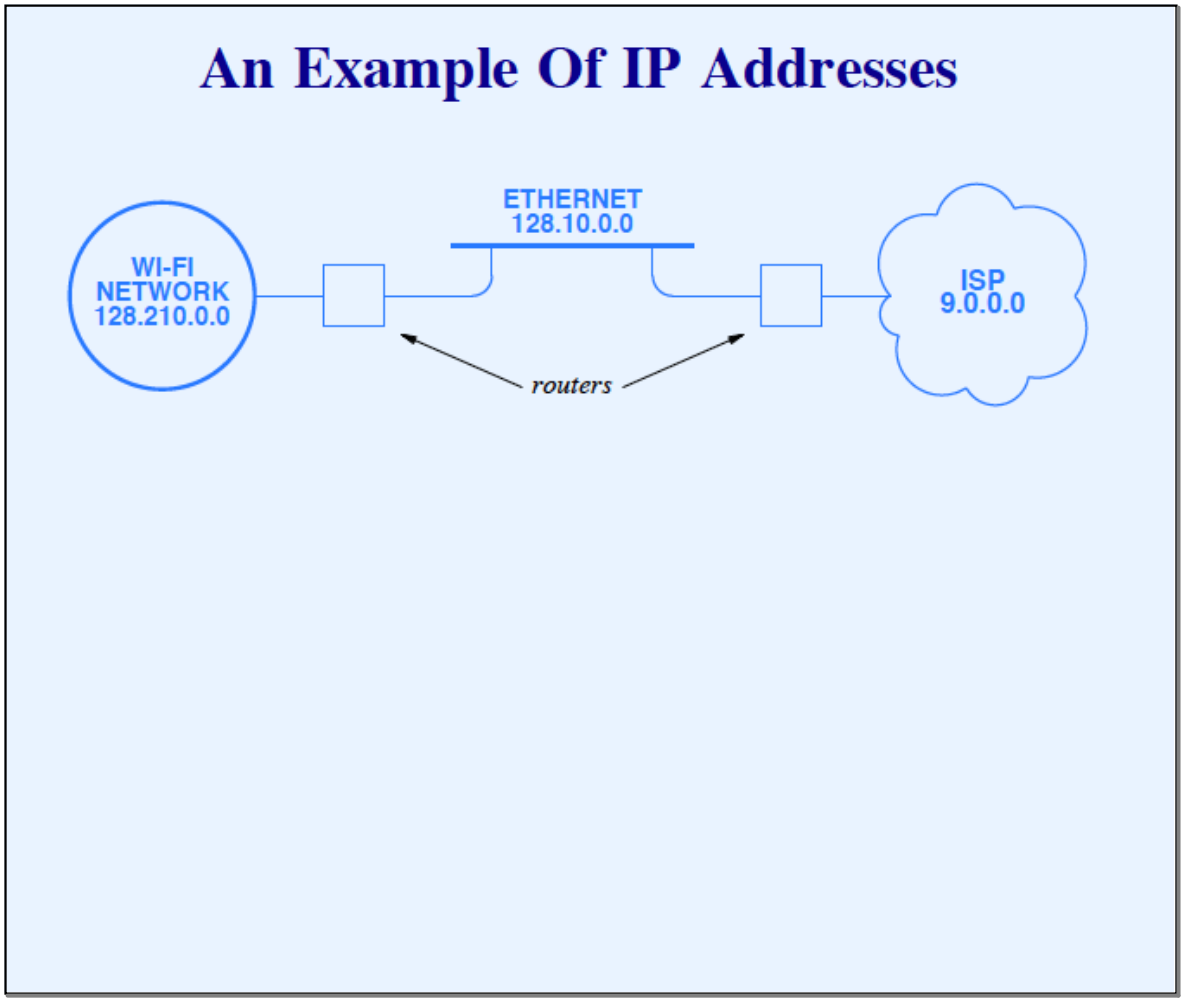
Classful Address Ranges

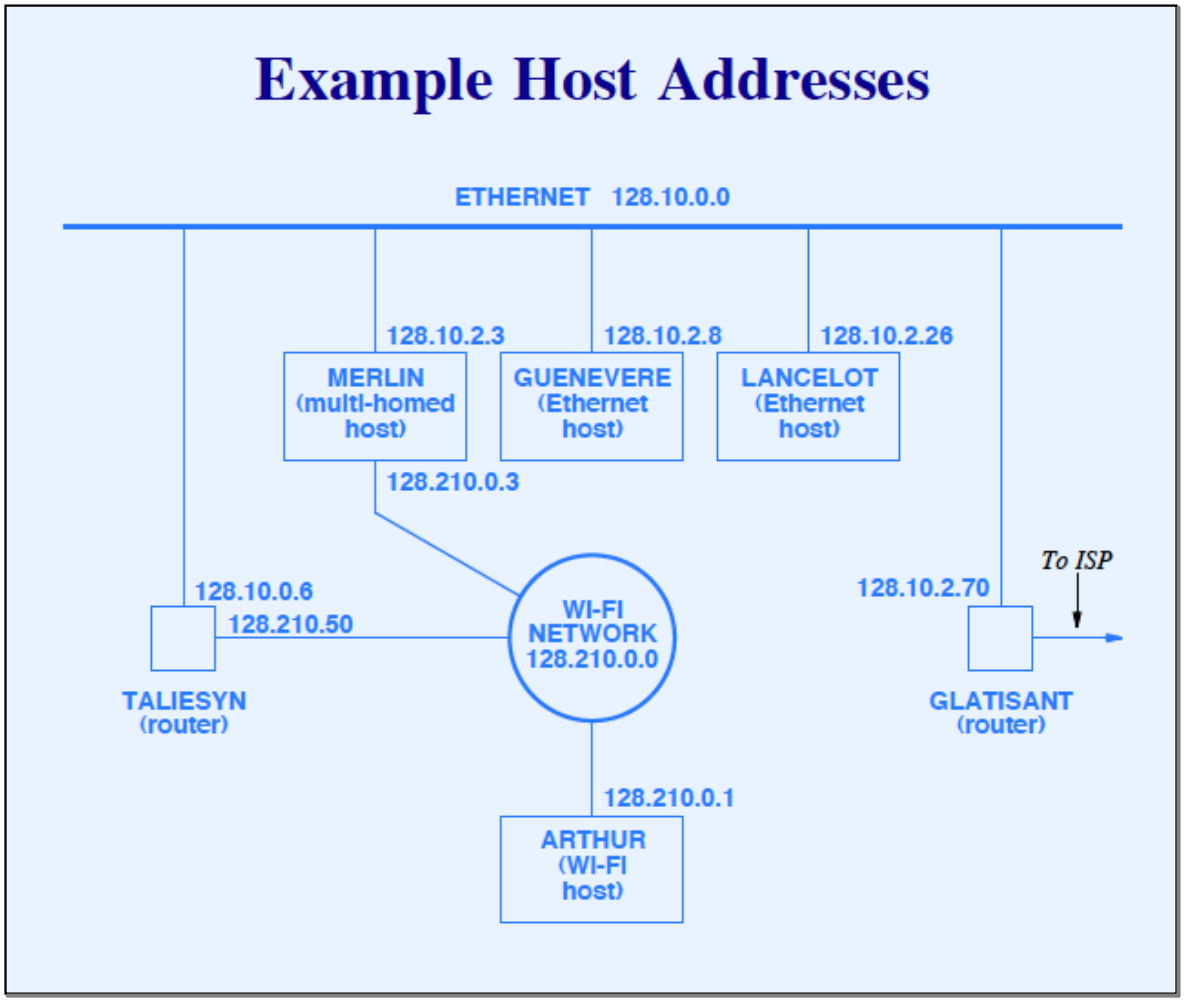
Class	Lowest Address	Highest Address
A	1.0.0.0	126.0.0.0
B	128.1.0.0	191.255.0.0
C	192.0.1.0	223.255.255.0
D	224.0.0.0	239.255.255.255
E	240.0.0.0	255.255.255.254

Summary Of Address Conventions



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
128.10.0.6
128.210.50
WI-FI NETWORK 128.210.0.0
128.10.2.70
To ISP
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

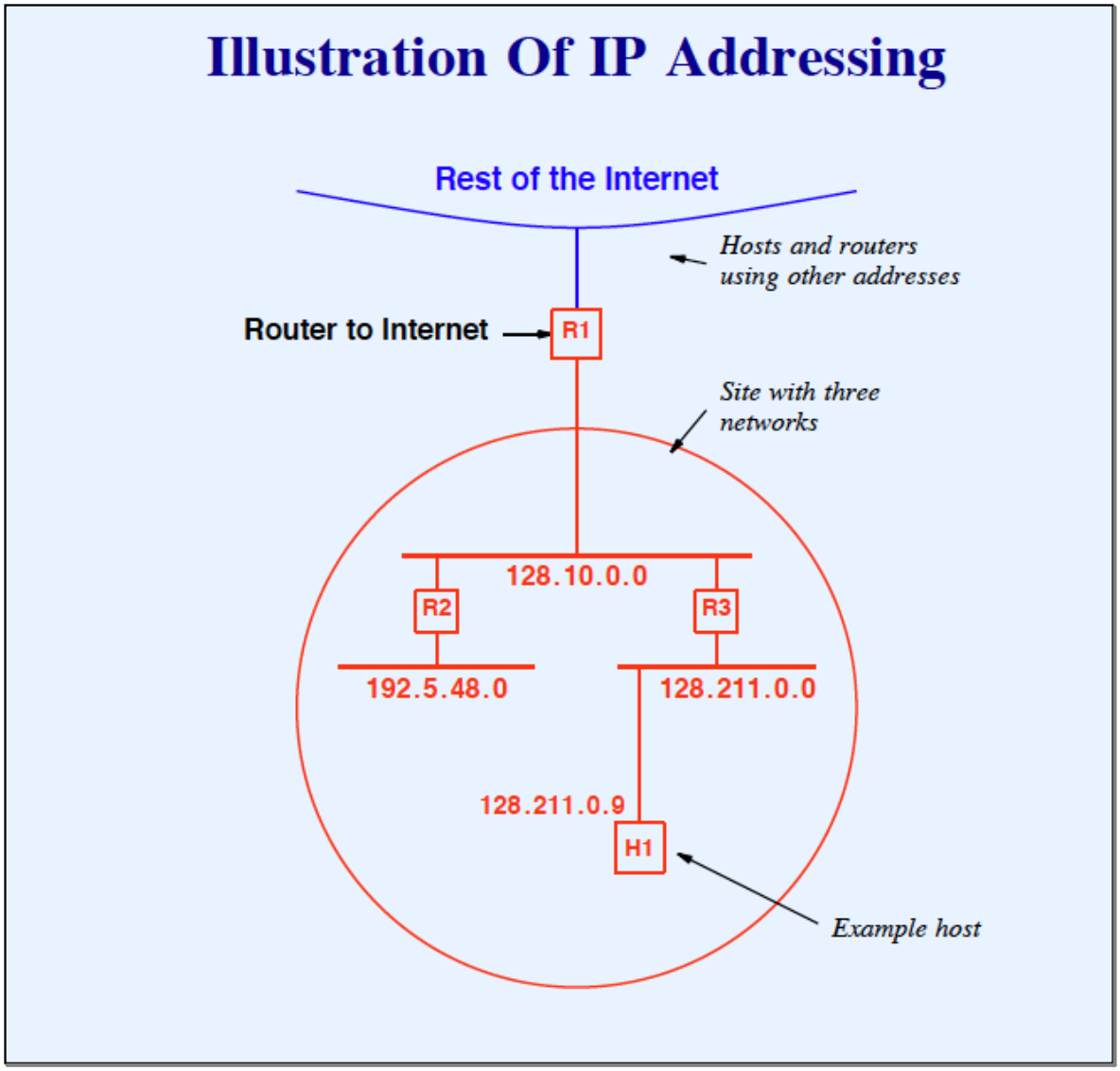


Illustration Of IP Addressing
Rest of the Internet
Hosts and routers
using other addresses
Router to Internet
R1
Site with three
networks
128.10.0.0
R2
R3
192.5.48.0
128.211.0.0
128.211.0.9
H1
Example host

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