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
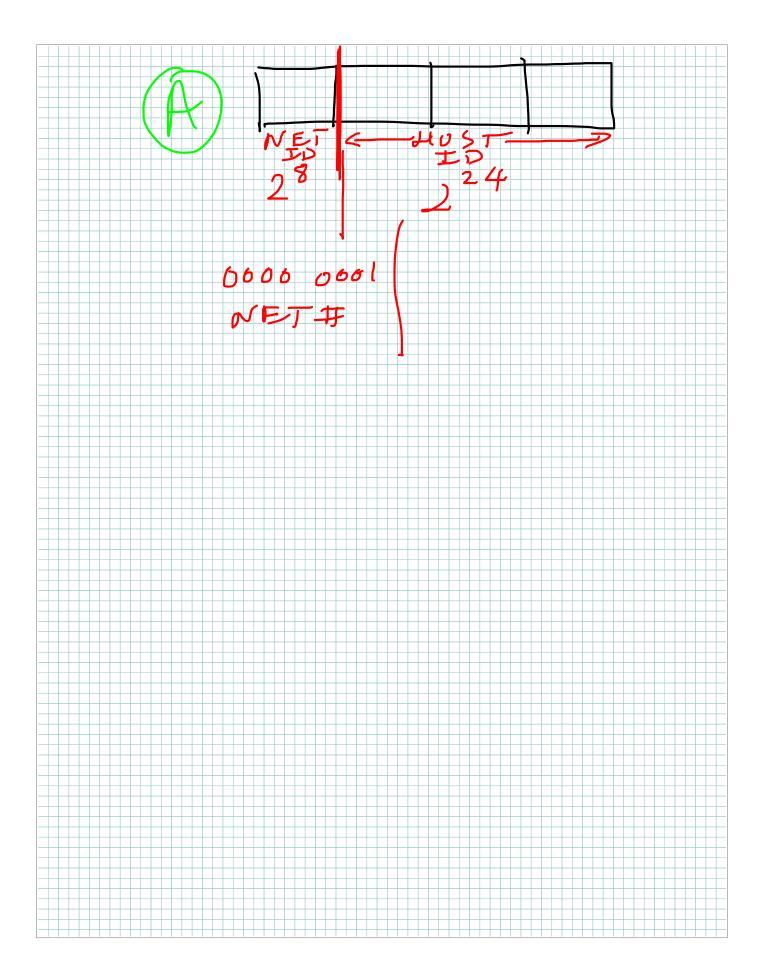
- Used by Internet applications

IP Address Details

- 32-bit binary value

- Unique value assigned to each host in Internet

- Values chosen to make routing efficient
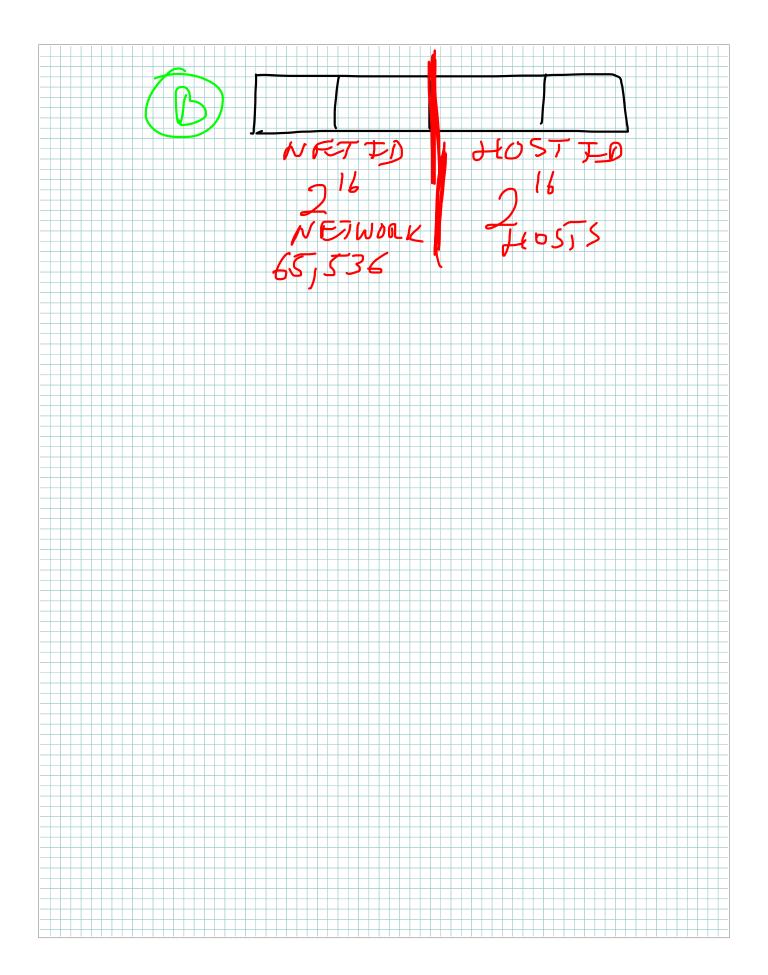
IP Address Division
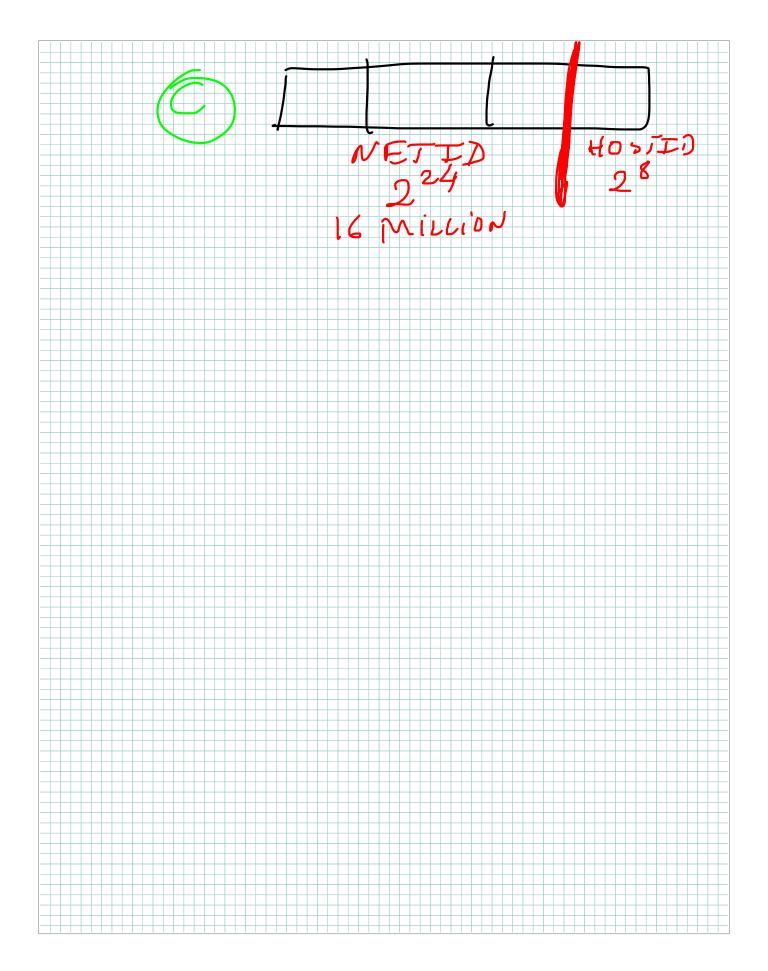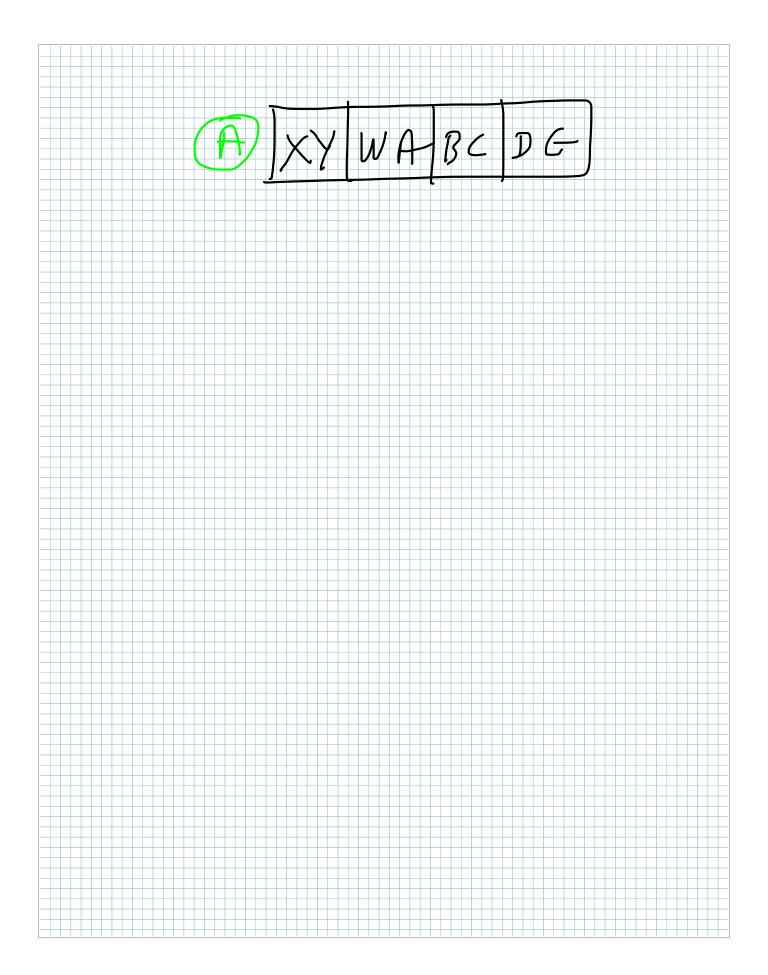
- Address divided into two parts

    - Prefix (network ID) identifies network to which host attaches

    - Suffix (host ID) identifies host on that network

(A)

NET ID 2^8 HOST ID 2^{24}

0000 0001
NET #

(B)

NET ID | HOST ID

2^{16}
NETWORK
65,536

2^{16}
HOSTS

NETID
2^{24}
16 MILLION

HOSTID
2^8

(A) | XY | WA | BC | DG |

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

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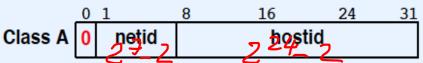
Division Of Internet Address Into Prefix And Suffix

- 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

	0 1	8	16	24	31
Class A	0	netid	hostid		

$2^7 - 2$ $2^{24} - 2$

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

	0 1	8	16	24	31
Class B	1 0	netid	hostid		

$2^{14} - 2$ $2^{16} - 2$
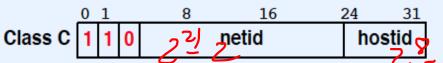
Class B Addresses are used for intermediate size networks that have up to 2^{16} (i.e. up to 65,536) hosts.

- · 14 Bits for netid
- · 16 Bits for hostid

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Original IPv4 Address Classes
Three Principle Classes

```
       0  1        8        16      24    31
Class C 1 1 0      netid              hostid
```

$2^{21}-2$ 2^8-2
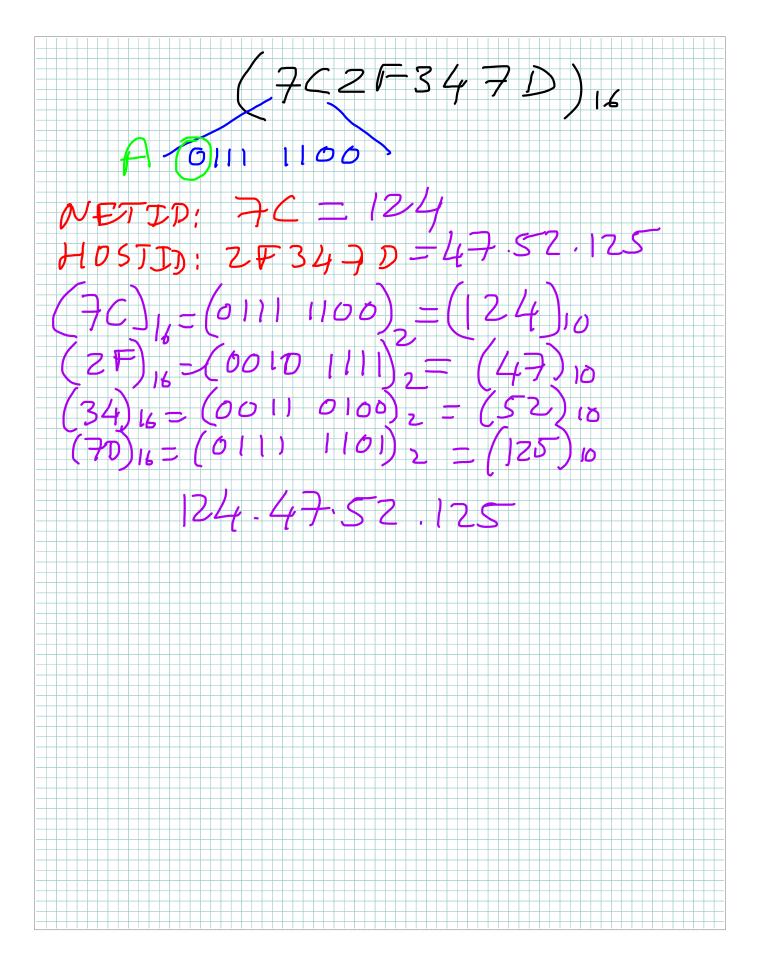
Class C Addresses are used for networks that have less than 2^8 (i.e. less than 256) hosts.

- 21 Bits for netid
- 8 Bits for hostid

Original IPv4 Address Classes
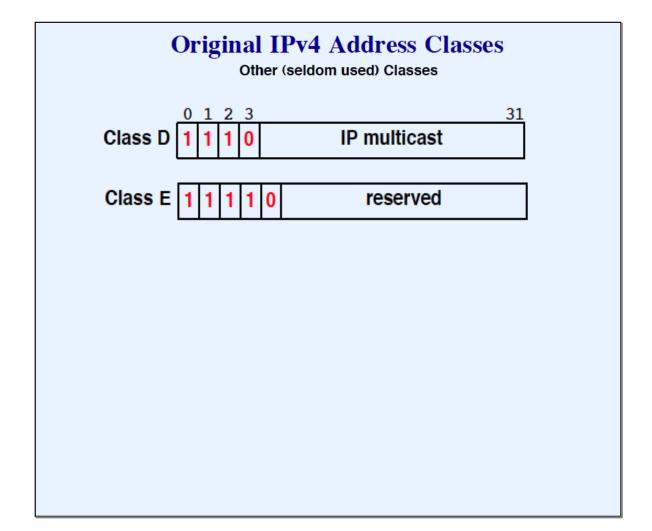## Other (seldom used) Classes

	0	1	2	3		31
Class D	1	1	1	0	IP multicast	

| Class E | 1 | 1 | 1 | 1 | 0 | reserved |

$$(7C2F347D)_{16}$$

A $\underline{0111 \quad 1100}$

NETID: $7C = 124$

HOSTID: $2F347D = 47.52.125$

$(7C)_{16} = (0111\ 1100)_2 = (124)_{10}$

$(2F)_{16} = (0010\ 1111)_2 = (47)_{10}$

$(34)_{16} = (0011\ 0100)_2 = (52)_{10}$

$(7D)_{16} = (0111\ 1101)_2 = (125)_{10}$

$$124.47.52.125$$

$(A37F2E4D)_{16}$

B $(1010\ 0011)$

NETID: $A37F = 163.127$
HOSTID: $2E4D = 46.77$

$(A3)_{16} = (1010\ 0011)_2 = (163)_{10}$
$(7F)_{16} = (0111\ 1111)_2 = (127)_{10}$
$(2E)_{16} = (0010\ 1110)_2 = (46)_{10}$
$(4D)_{16} = (0100\ 1101)_2 = (77)_{10}$

$163.127.46.77$

$$(D1\ 43\ 2F\ 7A)_{16}$$

C 1/01 0001

NETID : D1432F = 209.67.47

HOST ID : 7A = 122

$(D1)_{16} = (1101\ 0001)_2 = (209)_{10}$

$(43)_{16} = (0100\ 0011)_2 = (67)_{10}$

$(2F)_{16} = (0010\ 1111)_2 = (47)_{10}$

$(7A)_{16} = (0111\ 1010)_2 = (122)_{10}$

209.67.47.122

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

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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 <mark>directed broadcast</mark> 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
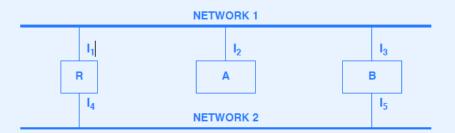
- More later in the course

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

NETWORK 1

I$_1$ I$_2$ I$_3$

R   A   B

I$_4$ I$_5$

NETWORK 2

- Knowing that B is multi-homed increases reliability

- If interface I$_3$ is down, host A can send to the interface I$_5$

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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

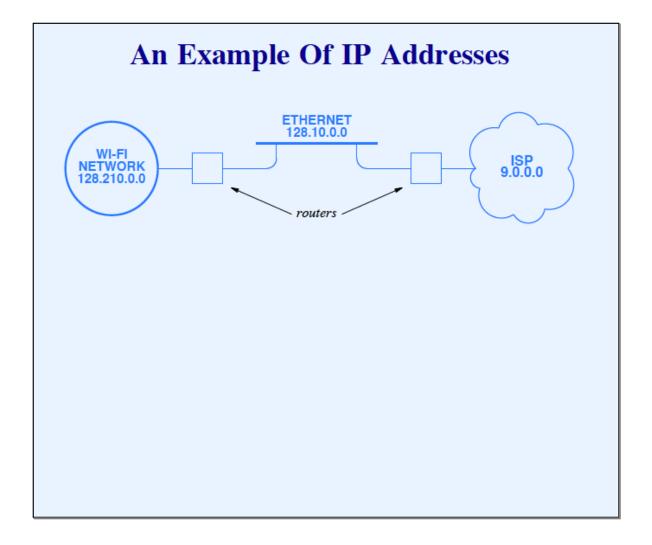| Class	Lowest Address	Highest Address
A	1.0.0.0	126.0.0.0
B	128.1.0.0	191.255.0.0
C	192.0.1.0	223.255.255.0
D	224.0.0.0	239.255.255.255
E	240.0.0.0	255.255.255.254

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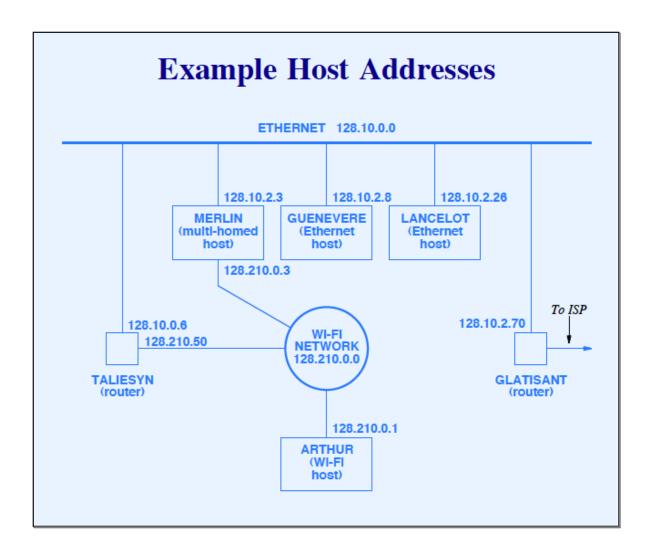
Summary Of Address Conventions

| 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
128.210.50

128.10.2.70

WI-FI
NETWORK
128.210.0.0

TALIESYN
(router)

GLATISANT
(router)

128.210.0.1

ARTHUR
(WI-FI
host)
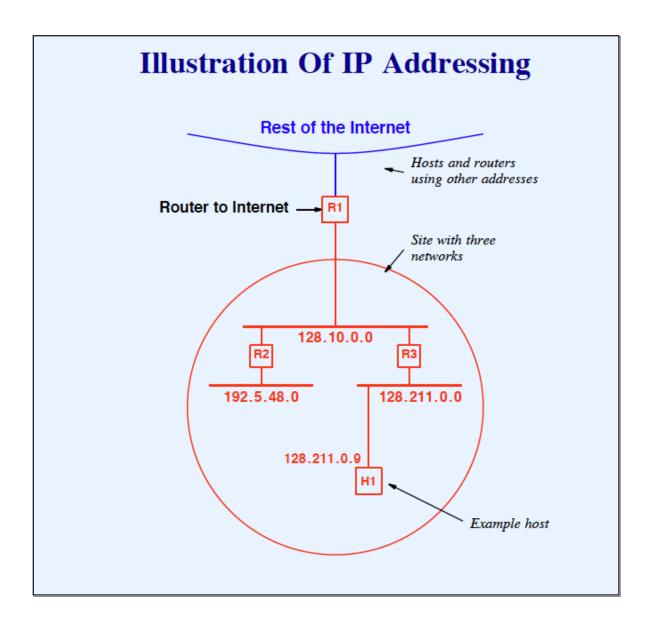
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Another Addressing Example

- 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