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

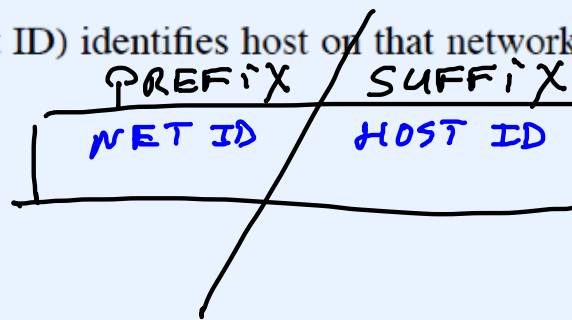- Used by Internet applications
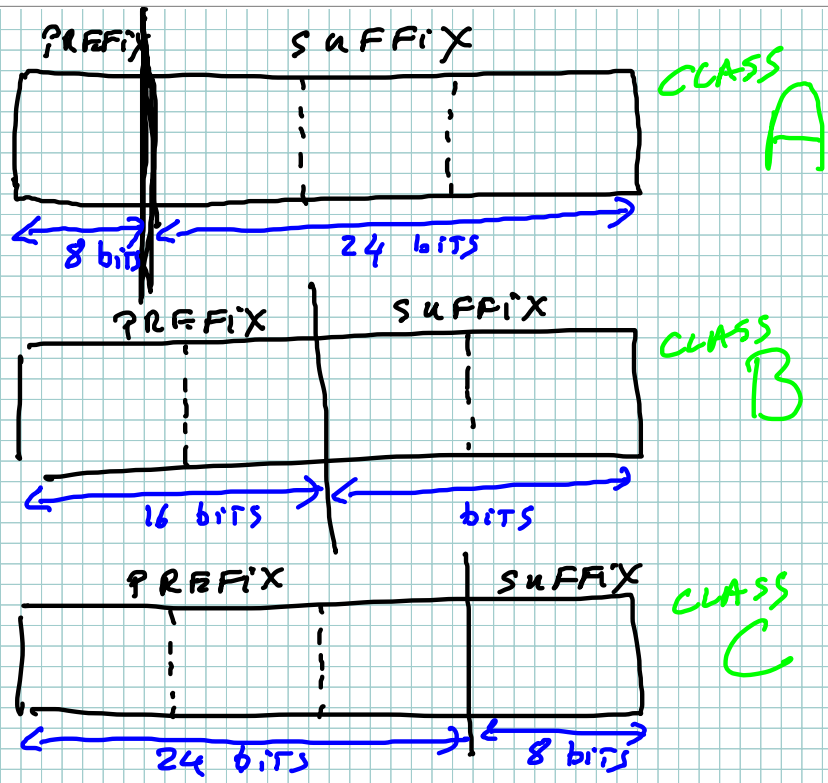
IP Address Details

- 32-bit binary value 4 BYTES (IPV4)

- Unique value assigned to each host in Internet

- Values chosen to make routing efficient
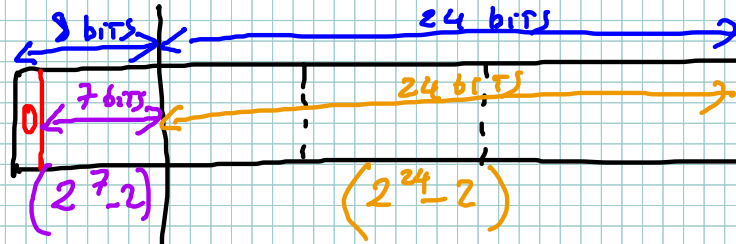
  IPv6 (16 BYTES)

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

PREFIX / SUFFIX

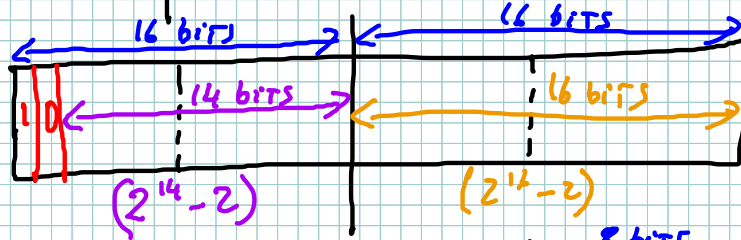*NET ID / HOST ID*

PREFIX   SUFFIX   CLASS A

← 8 bits → ← 24 bits →

PREFIX   SUFFIX   CLASS B

← 16 bits → ← bits →

PREFIX   SUFFIX   CLASS C

← 24 bits → ← 8 bits →

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

9 bits — 24 bits

0 — 7 bits — 24 bits

(2^7-2) — $(2^{24}-2)$

A

$(2^{14}-2)(2^{16}-2)$

16 bits — 16 bits

1 0 — 14 bits — 16 bits

$(2^{14}-2)$ — $(2^{14}-2)$

B

$(2^{21}-2)(2^8-2)$

24 bits — 8 bits

1 1 0 — 21 bits — 8 bits

$(2^{21}-2)$ — (2^8-2)

C
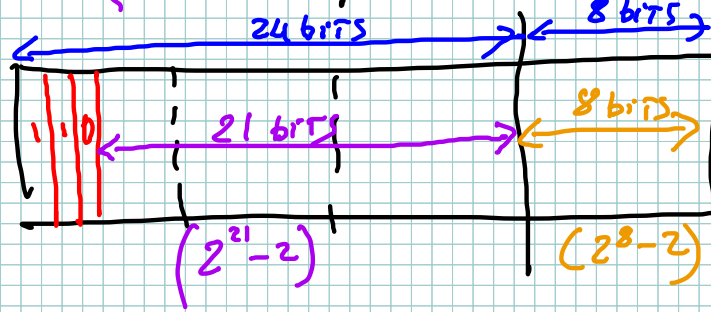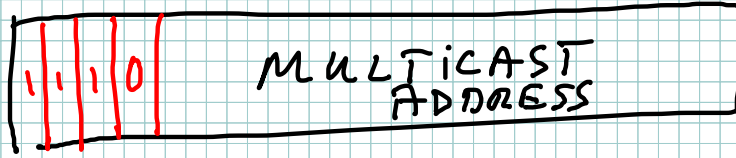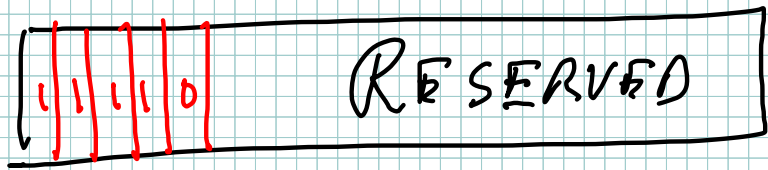
| 1 | 1 | 1 | 0 | MULTICAST ADDRESS | CLASS D |

| 1 | 1 | 1 | 1 | 0 | RESERVED | CLASS E |

06 7D 8F BC

a) 06   [0000 0110]   CLASS A

b) NET ID   06

c) HOST ID   7D 8F BC

d) 06 . 125 . 143 . 188

↑   ↑   ↑   ↑

06   7D   8F   BC

7D

$7 \times 16 = 112$

$D \times 1 = 13$

125

128 64 32 16	8 4 2 1
0 1 1 1	1 1 0 1

9A726BCF

a) 9A   [10]01 1010 B

b) NETID   9A72

c) HOST ID   6BCF

d)   154 . 114 . 107 . 207

   9A   72   6B   CF

DA9B573D

a) DA   [110]1   1010   C

b) NETID   DATB57

c) HOST   3D

d) 218 . 155 . 87 . 61

DA   9B   57   3D

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

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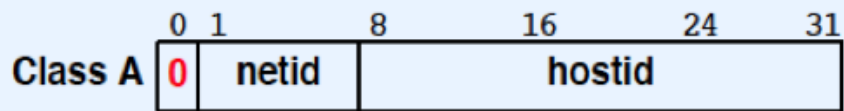
Class A Addresses are used for the handful of networks that have more than 2^{16} (i.e. more than 65,536) hosts.

- 7 Bits for netid
- 24 Bits for hostid

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

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

0	1		8	16	24	31

Class C | 1 | 1 | 0 | netid | hostid |
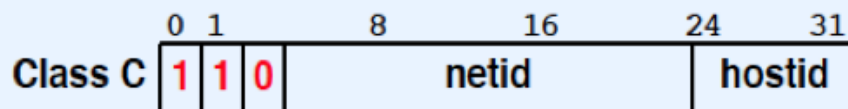
Class C Addresses are used for networks that have less than 2^8 (i.e. less than 256) hosts.

- 21 Bits for netid
- 8 Bits for hostid

Original IPv4 Address Classes

Other (seldom used) Classes
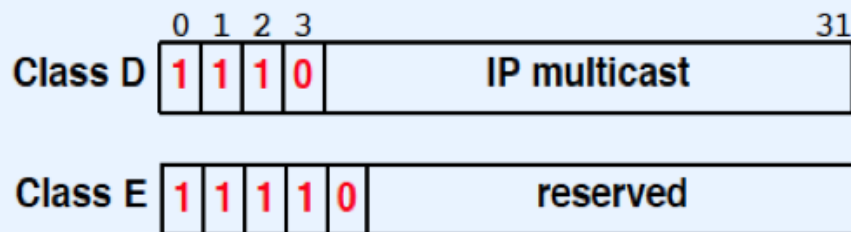
Important Property

- 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

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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.

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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

NETWORK 1

I_1	I_2	I_3
R	A	B
I_4		I_5

NETWORK 2
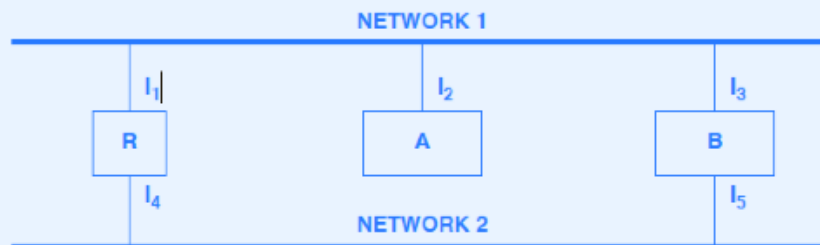
- Knowing that B is multi-homed increases reliability

- If interface I_3 is down, host A can send to the interface I_5

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   **GUENEVERE**   **LANCELOT**
(multi-homed   (Ethernet   (Ethernet
host)   host)   host)

128.210.0.3

To ISP

128.10.0.6   128.10.2.70
128.210.50

**WI-FI
NETWORK
128.210.0.0**

TALIESYN   **GLATISANT**
(router)   (router)

128.210.0.1

ARTHUR
(WI-FI
host)

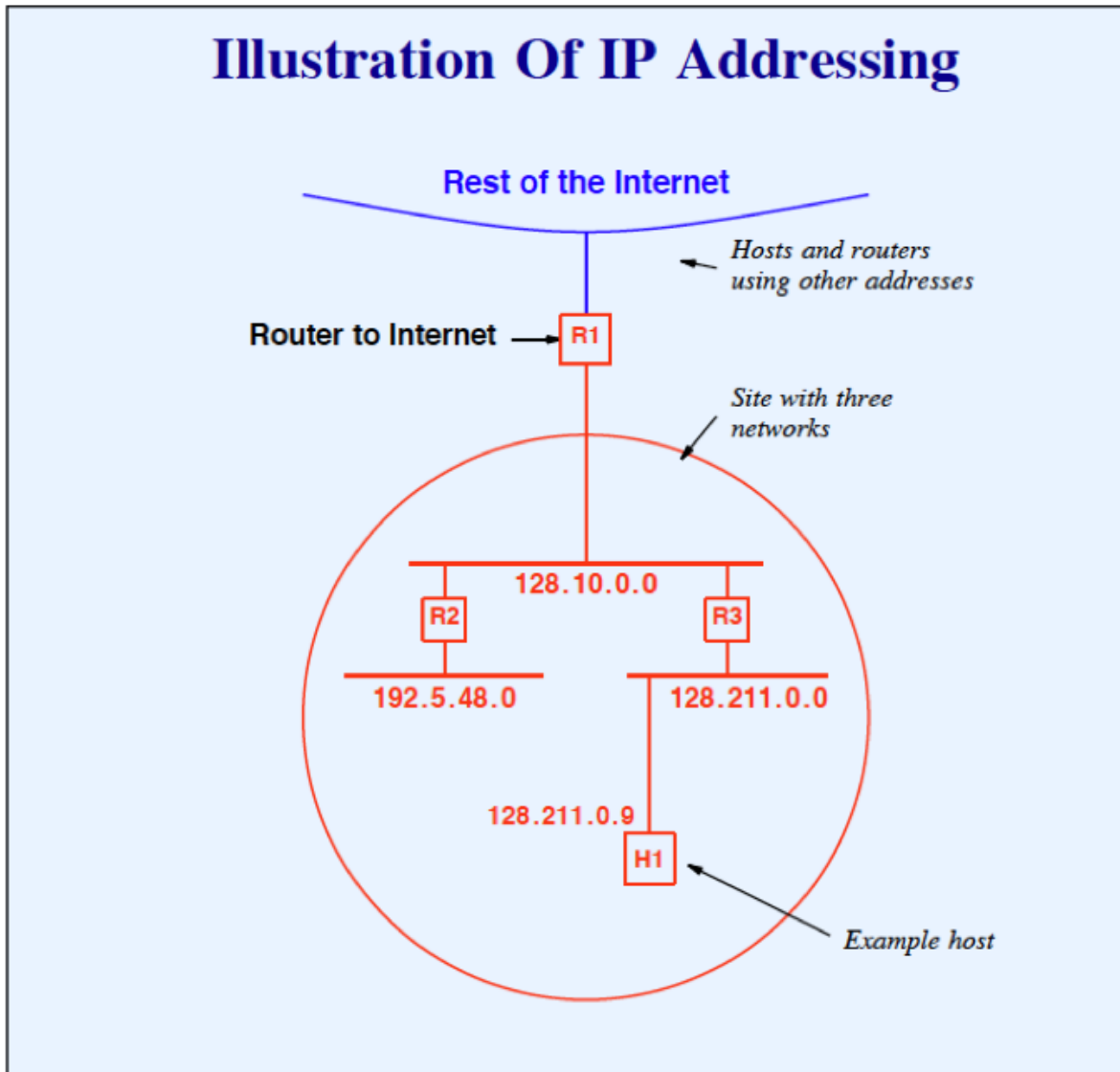**Internetworking With TCP/IP**   **29**
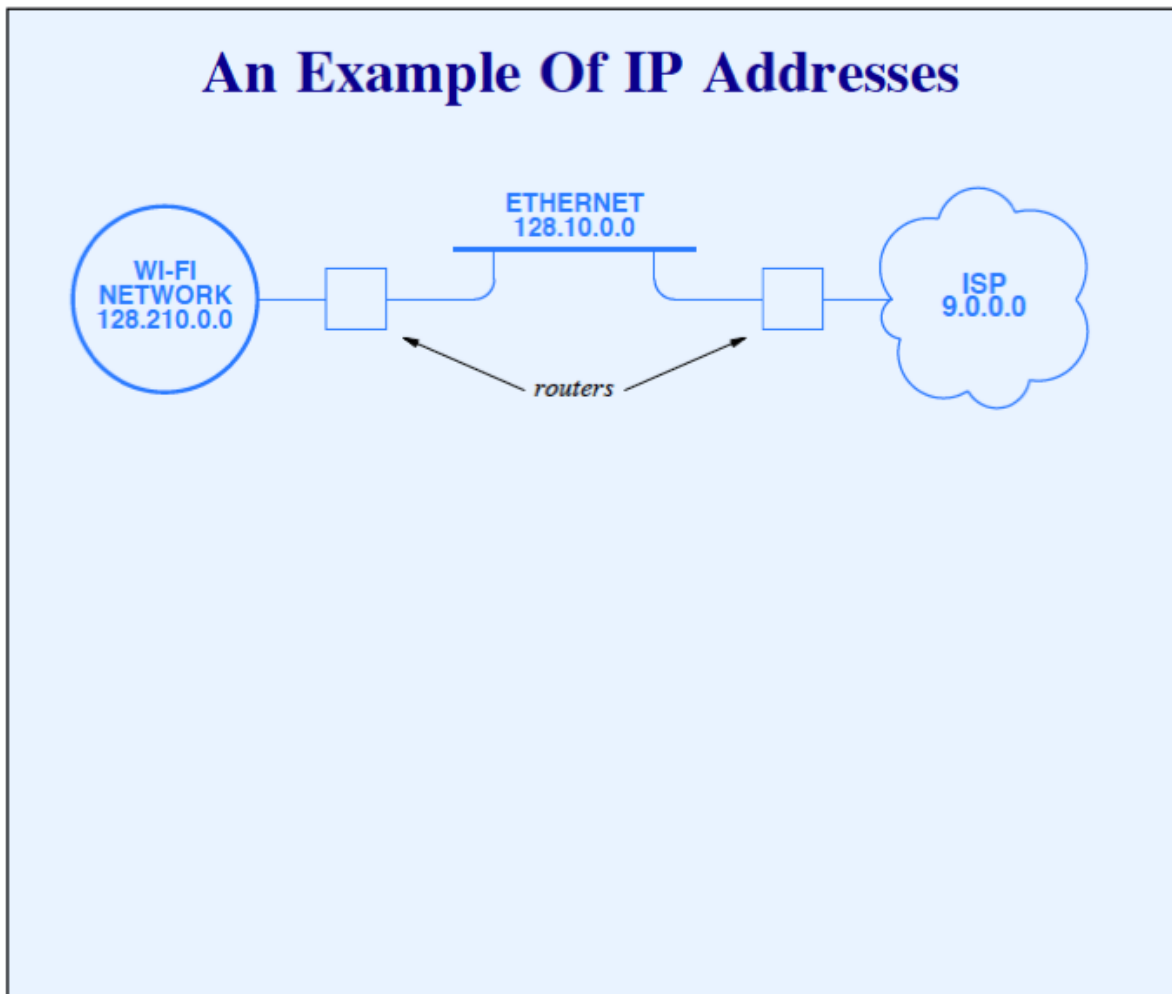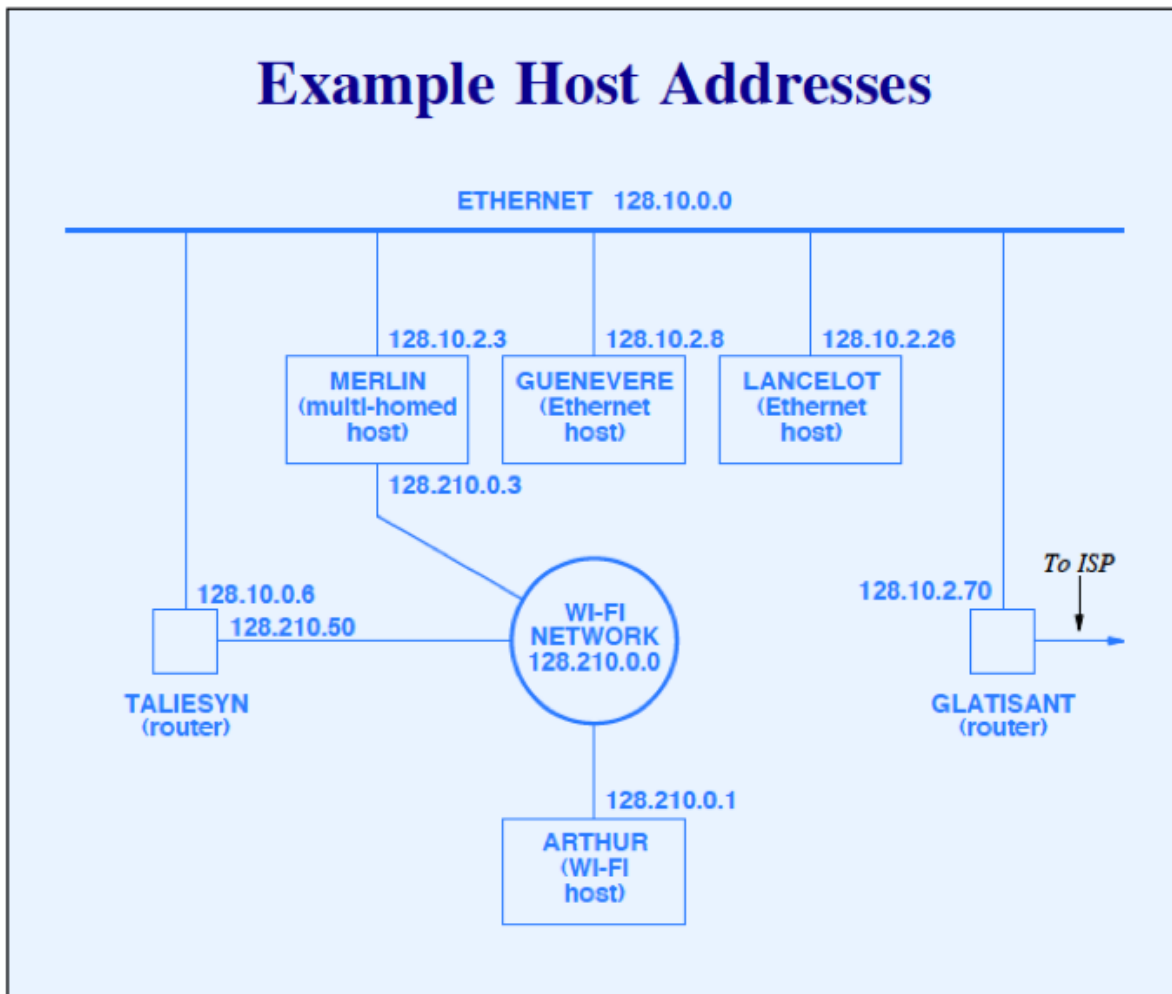
Another Addressing Example

- 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