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

0
1
2
3
4
5
6
7
8
9
10

3 4 5

100's 10's 1's

10^2 10^1 10^0

$$\begin{array}{r} ^1 9 \\ +\ 1 \\ \hline 10 \end{array}$$

0
1
2
3
4
5
6
7
8
9

BASE 5

3 4 4

25's 5's 1's
5^2 5^1 5^0

0
1
2
3
4

$(4 \times 5^0) = 4$

$+ (4 \times 5^1) = 20$

$+ (3 \times 5^2) = \dfrac{75}{99}$

$$(99)_{10} \rightarrow (\ ?\ )_5$$

$$344$$

$$
\begin{array}{r}
99 \\
-75 \\
\hline
24 \\
-20 \\
\hline
4
\end{array}
$$

$$
\begin{array}{r}
1 \\
\overline{5} \\
\overline{25} \\
\overline{125}
\end{array}
$$

-

BASE 10	BASE 2	BASE 10	BASE 2
0	0000	11	1011
1	0001	12	1100
2	0010	13	1101
3	0011	14	1110
4	0100	15	1111
5	0101		
6	0110		
7	0111		
8	1000		
9	1001		
10	1010		

$$1\ 0\ 1\ 1\ \ 1\ 0\ 0\ 1$$

128 64 32 16 8 4 2 1

2
128
+ 32
+. 1.6
+ 8
+ 1
―――――
185

$(185)_{10} \rightarrow (\qquad)_2$

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

185
−128
――――
57
32
――――
25
−16
――――
9
−8
――――
1
−1
――――
0

0	0000	0
1	0001	1
2	0010	2
3	0011	3
4	0100	4
5	0101	5
6	0110	6
7	0111	7

8	1000	8
9	1001	9
10	1010	A
11	1011	B
12	1100	C
13	1101	D
14	1110	E
15	1111	F

C D

16's 1's

16^1 16^0

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

$$(12 \times 16) + (13 \times 1)$$

$$192 + 13$$

$$205$$

—

1100 1101

2
128
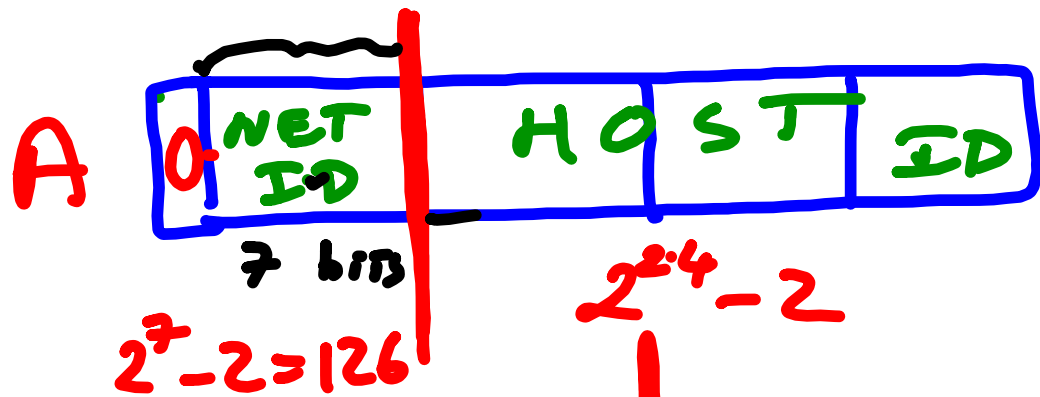+ 64
+ 8
+ 4
+ 1
—————
205

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 0 NET ID | HOST ID

7 bits

$2^{7}-2=126$

$2^{24}-2$

B 10 NET ID | HOST ID

14 bits

$2^{14}-2$

$2^{14}-2$

C 110 NET ID | HOST ID

21 bits

$2^{21}-2$

$2^{8}-2$
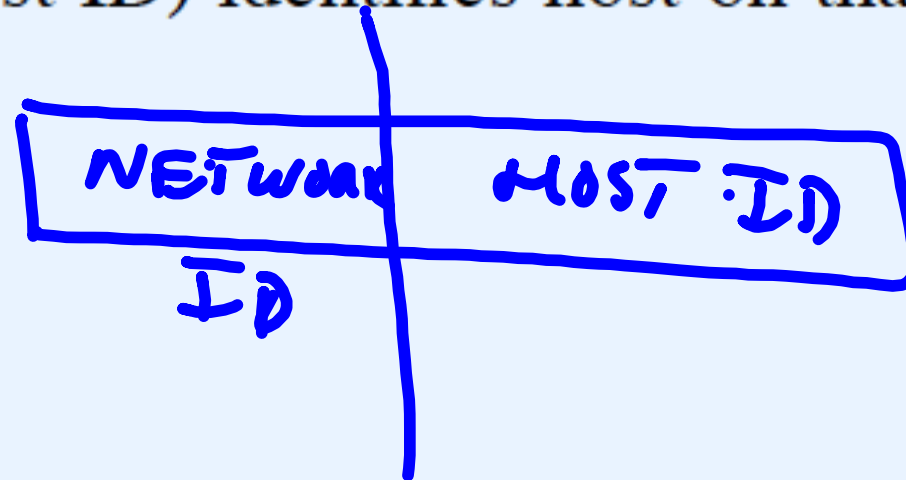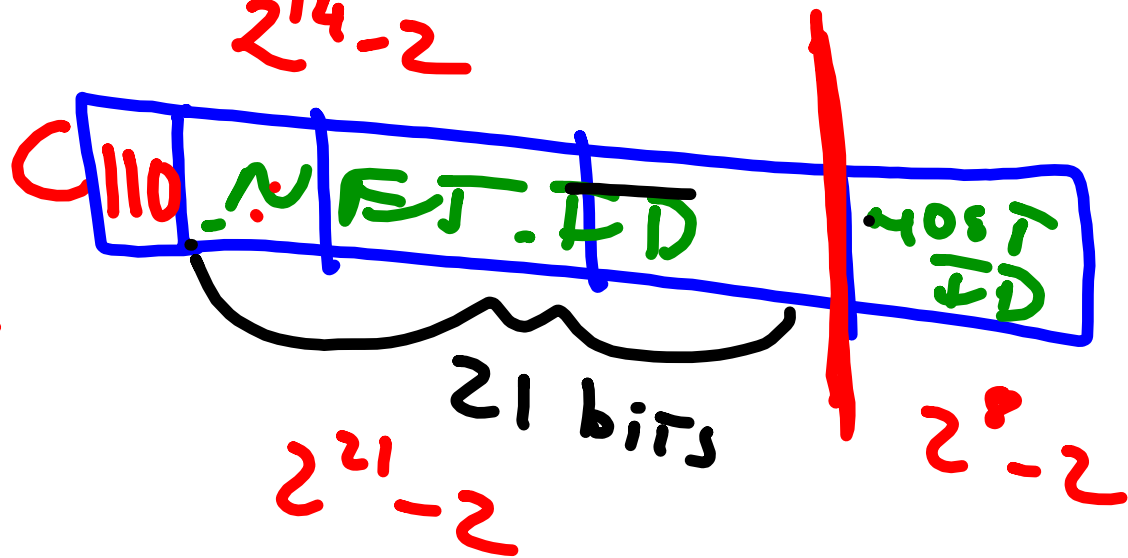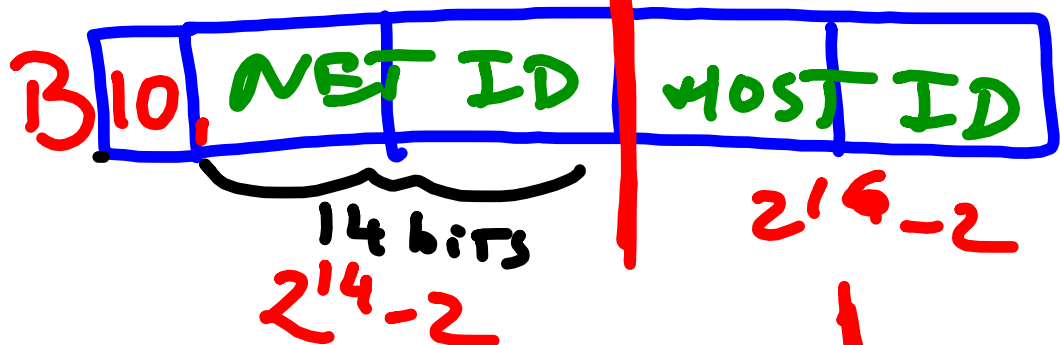
Classful Addressing

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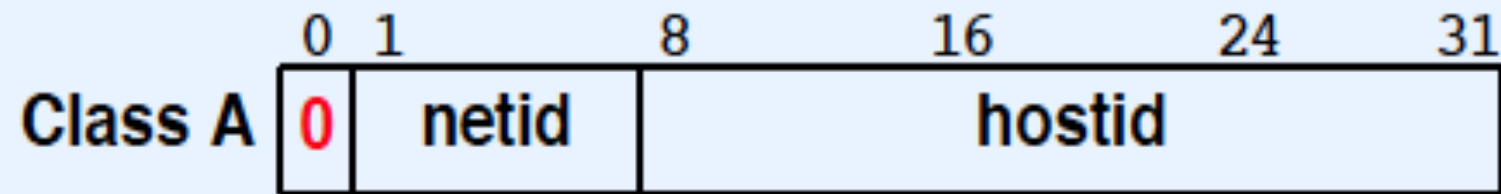
Class A Addresses are used for the handful of networks that have more than 2^{16} (i.e. more than 65,536) hosts.

- 7 Bits for netid
- 24 Bits for hostid

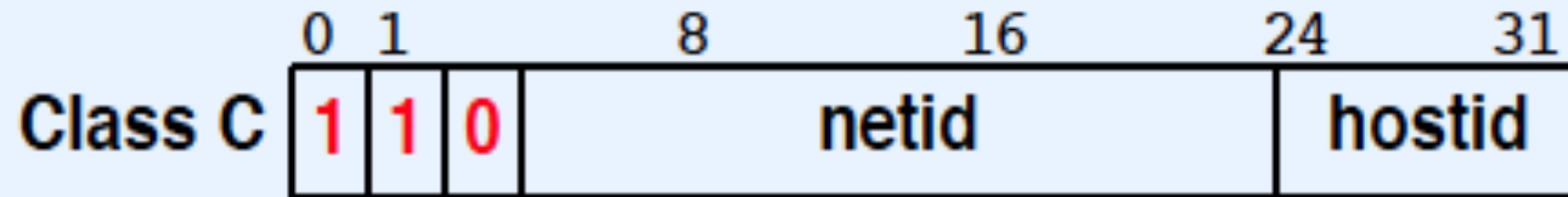| 0 1	8	16	24	31

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

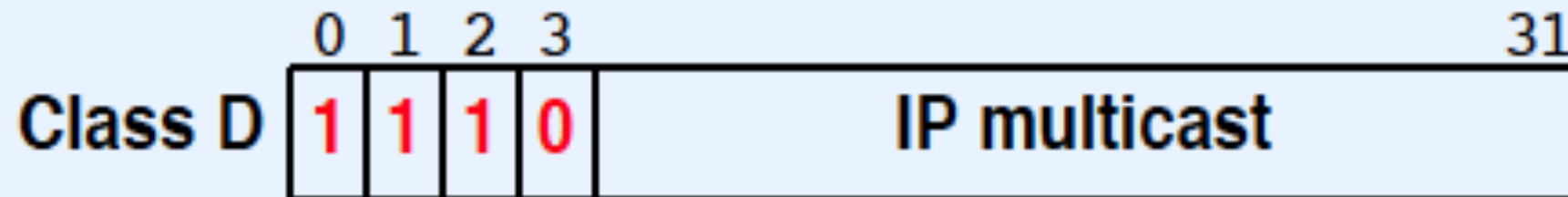| 0	1		8	16	24	31

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

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

8 8C C

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

128
+ 8
+ 4
―――
140

8C 3B 2E F1

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

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

CLASS B
NETID 8C3B
HOSTID 2EF1
DOTTED
    DECIMAL 140.59.46.241

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

32
+ 8
+ 4
+ 2
―――
46

4.6 2C 7B 2E

0100 0110

CLASS A

NETID 46

HOST ID 2C7B2E

DOTTED
DECIMAL 70.44.123.46

64 32 16 8 4 2 1
0010 1100

| 0 | 0 | 1 | 0 | 1 | 1 | 1 | 0 |

C1 F7 2B 3F

11000001

CLASS C

NETID C1F72B

HOSTID 3F

¿

193.247.43.63

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
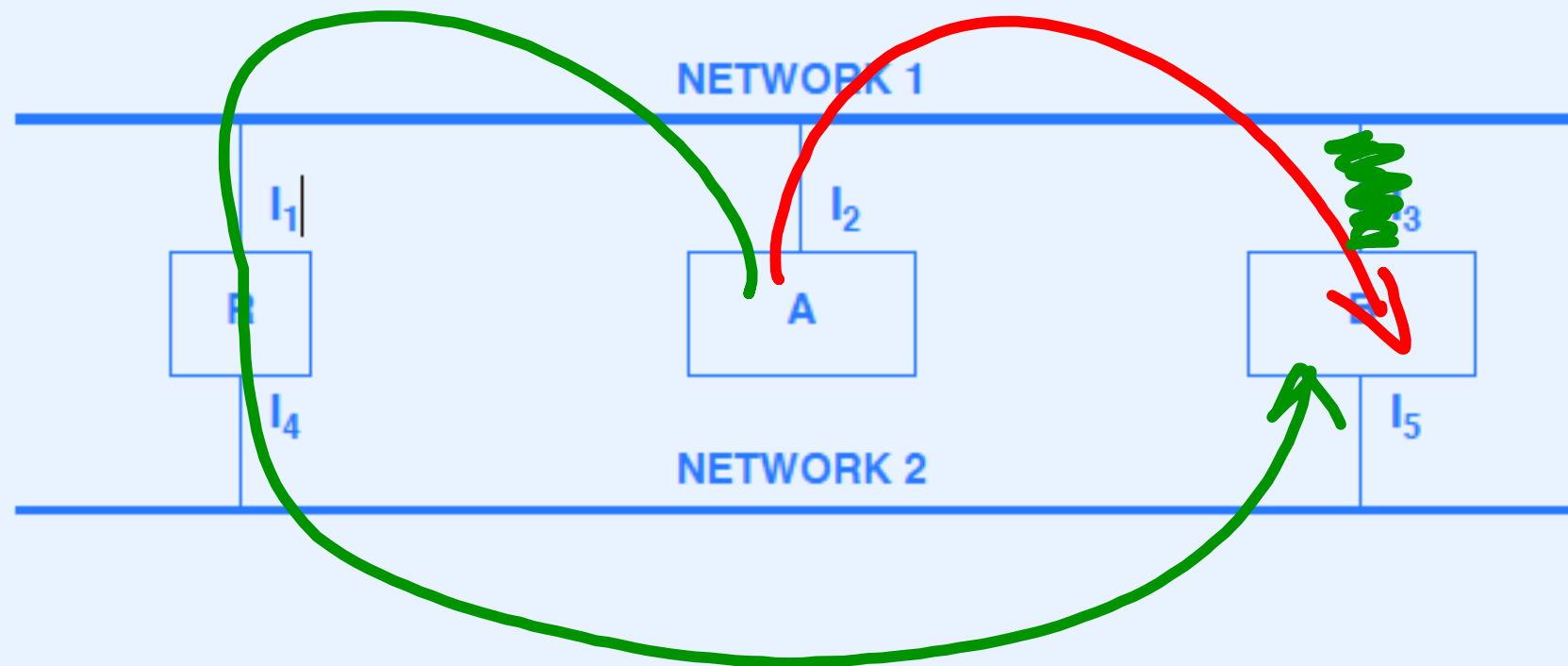
- Knowing that B is multi-homed increases reliability

- 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

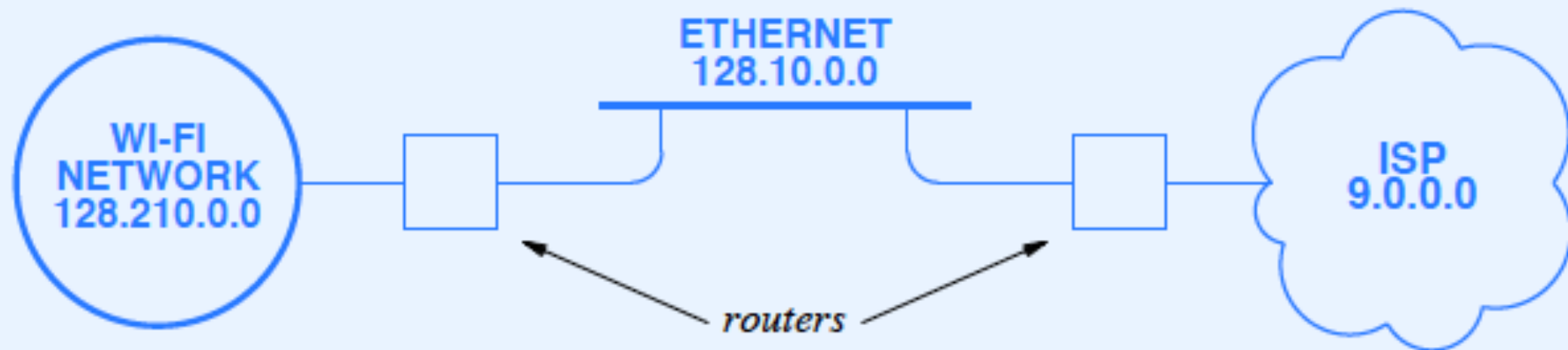| Class	Lowest Address	Highest Address
A	1.0.0.0	126.0.0.0
B	128.1.0.0	191.255.0.0
C	192.0.1.0	223.255.255.0
D	224.0.0.0	239.255.255.255
E	240.0.0.0	255.255.255.254

Summary Of Address Conventions

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

WI-FI NETWORK 128.210.0.0 — **ETHERNET 128.10.0.0** — **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

WI-FI
NETWORK

TALIESYN
(router)

128.10.2.70

To ISP

GLATISANT
(router)

ARTHUR
(WI-FI
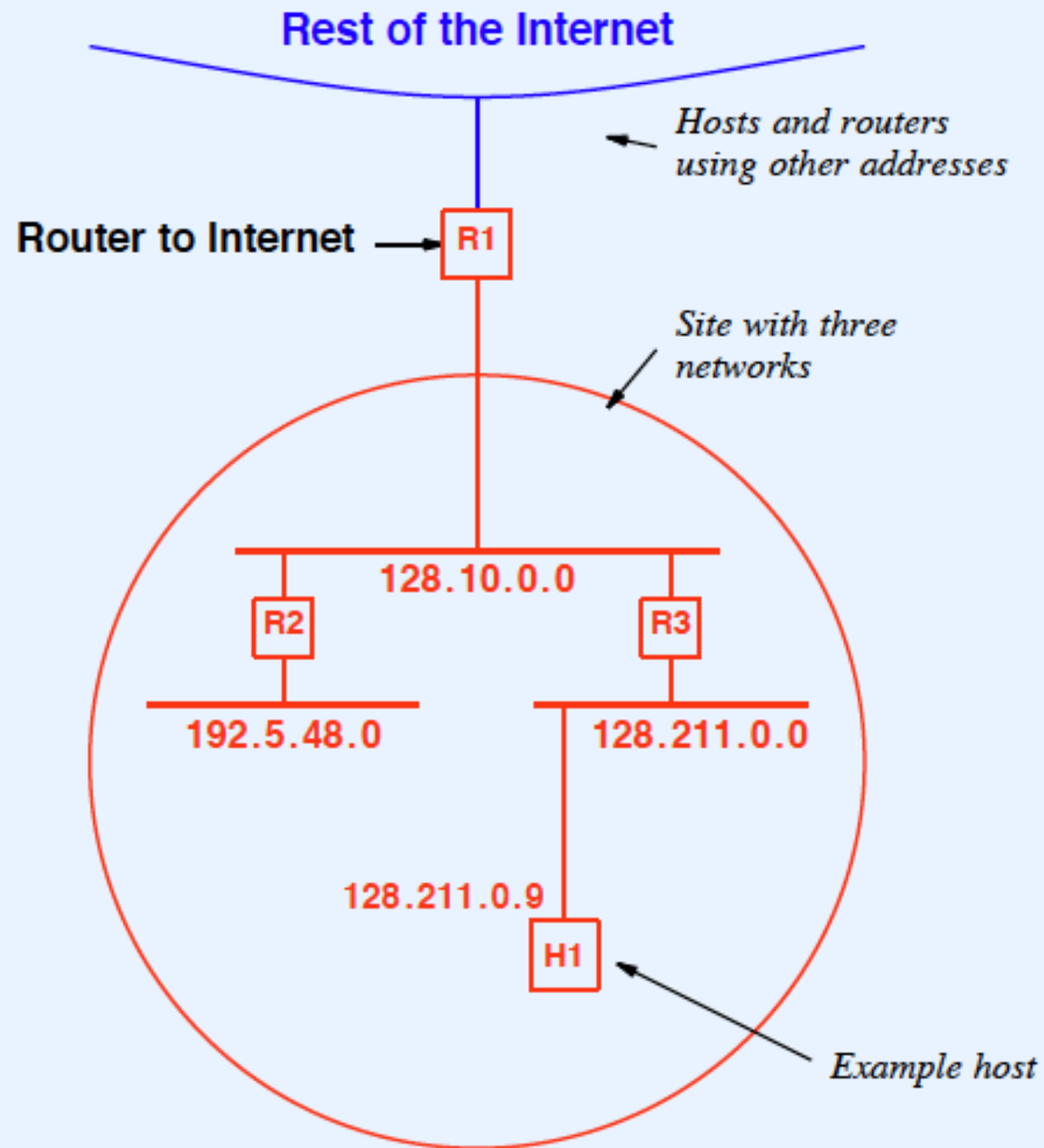host)
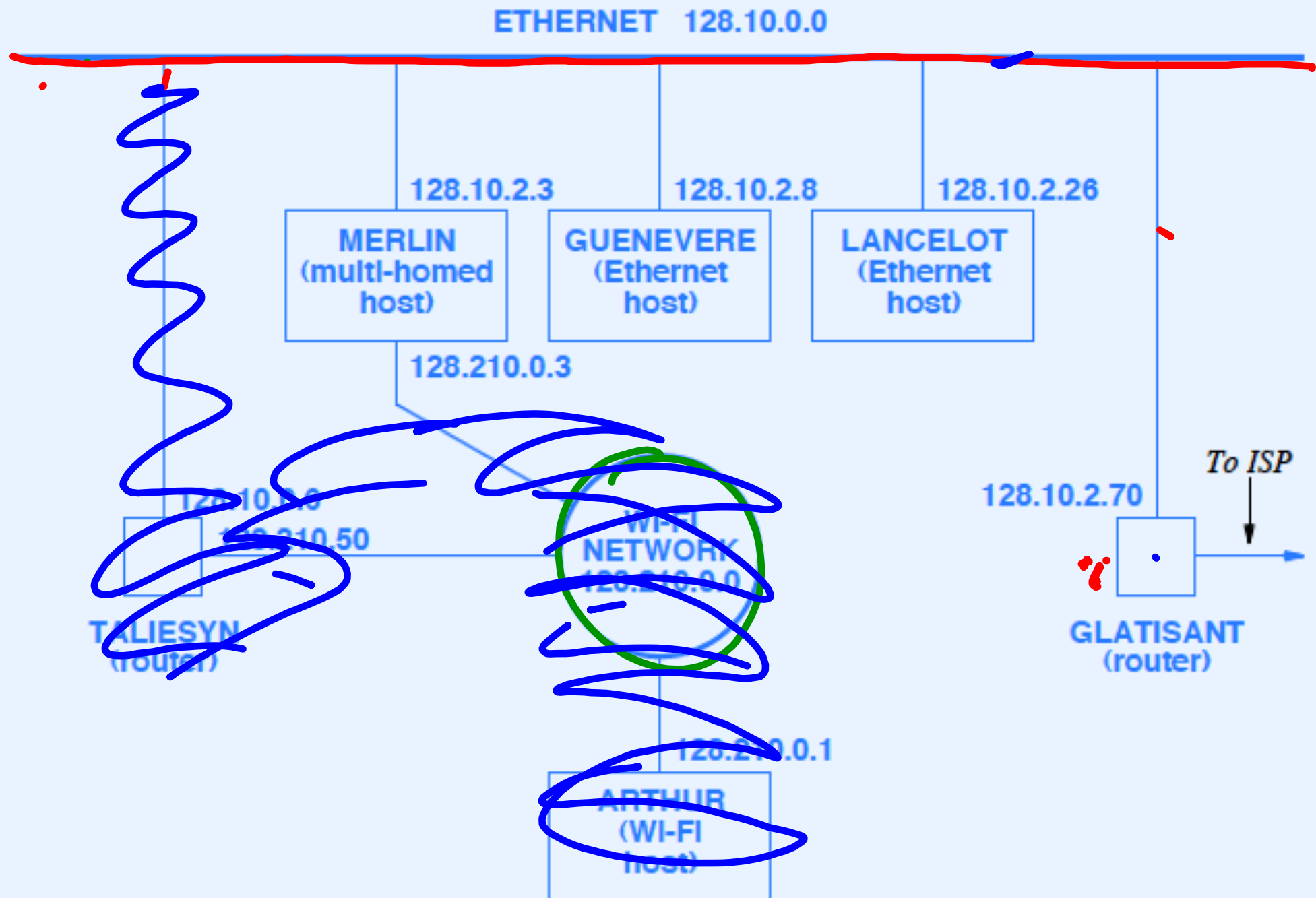
Another Addressing Example

- 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