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
NET ID
2^24
HOSP ID
2^8
16 MILLION
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
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
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

Class D 1 1 1 0  IP multicast

Class E 1 1 1 1 0  reserved
$A_{16} = (0111\ 1100)_{2} = (124)_{10}$
$2F_{16} = (0010\ 1111)_{2} = (47)_{10}$
$34_{16} = (0011\ 0100)_{2} = (52)_{10}$
$7D_{16} = (0111\ 1101)_{2} = (125)_{10}$

$124.47.52.125$
\[(A37F2E4D)_{16}\]

NETID: \[A37F = 163.127\]
HOSTID: \[2E4D = 46.77\]

\[(A3)_{16} = (10100011)_{2} = (163)_{10}\]
\[(7F)_{16} = (01111111)_{2} = (127)_{10}\]
\[(2E)_{16} = (00101110)_{2} = (46)_{10}\]
\[(4D)_{16} = (01001101)_{2} = (67)_{10}\]

\[163.127.46.77\]
NETID: D1432F = 209.67.47
HOSTID: 7A = 122

\[(D1)_{16} = (11010001)_{2} = (209)_{10}\]
\[(43)_{16} = (01100011)_{2} = (67)_{10}\]
\[(2F)_{16} = (00101111)_{2} = (47)_{10}\]
\[(7A)_{16} = (01111010)_{2} = (122)_{10}\]

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
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 I₃ is down, host A can send to the interface I₅
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

<table>
<thead>
<tr>
<th>Class</th>
<th>Lowest Address</th>
<th>Highest Address</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1.0.0.0</td>
<td>126.0.0.0</td>
</tr>
<tr>
<td>B</td>
<td>128.1.0.0</td>
<td>191.255.0.0</td>
</tr>
<tr>
<td>C</td>
<td>192.0.1.0</td>
<td>223.255.255.0</td>
</tr>
<tr>
<td>D</td>
<td>224.0.0.0</td>
<td>239.255.255.255</td>
</tr>
<tr>
<td>E</td>
<td>240.0.0.0</td>
<td>255.255.255.254</td>
</tr>
</tbody>
</table>
### Summary Of Address Conventions

<table>
<thead>
<tr>
<th>All 0s</th>
<th>This host</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>All 0s</td>
<td>Host on this net</td>
<td></td>
</tr>
<tr>
<td>All 1s</td>
<td>Limited broadcast (local net)</td>
<td></td>
</tr>
<tr>
<td>Net</td>
<td>Directed broadcast for net</td>
<td></td>
</tr>
<tr>
<td>127 Anything (often 1)</td>
<td>Loopback</td>
<td></td>
</tr>
</tbody>
</table>

Notes:  
1. Allowed only at system startup and is never a valid destination address.  
2. Never a valid source address.  
An Example Of IP Addresses
Example Host Addresses

![Diagram of host addresses and network connections]

- **Ethernet**: 128.10.0.0
- **Merlin** (multi-homed host): 128.10.2.3
- **Guinevere** (Ethernet host): 128.10.2.8
- **Lancelot** (Ethernet host): 128.10.2.26
- **Taliesyn** (router): 128.10.0.6, 128.210.50
- **Wi-Fi Network**: 128.210.0.0
- **Arthur** (Wi-Fi host): 128.210.0.1
- **To ISP**: 128.10.2.70

- **Glatisant** (router):
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

Router to Internet

128.10.0.0

192.5.48.0

128.211.0.9

H1

128.211.0.0

R2

R3

R1

Hosts and routers using other addresses

Site with three networks

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