Topic 5: Network Layer

Name and Address

Domain Name Server ⟶ names ⟺ addresses

- DNS name in ASCII string: (dns)
  - linux-1.ece.iastate.edu
- IP address in dotted-decimal ASCII string (dd):
  - 129.186.205.13
- IP address in 32-bit binary representation (b):
  - 10000001 10111010 11001101 00001101
- Difference between a DNS name and an IP address
  - Names are meaningful, easy to remember
    - Variable-length, difficult for router to process
  - Addresses have fixed length, rigid hierarchical structure
    - Easy for router to process

Internet Protocol

IPv4

IPv6 : 128 bits

IP address

- Each host connected to the Internet is assigned a unique 32-bit IP address that is used in all communications with that host
  - IP addresses do not specify an individual computer, but a connection to the Internet
    - A host might be "multi-homed"
    - IP addresses might be reused

IP address is unique but not permanent

MAC/physical address is unique and permanent

IP address

- Each IP address has two parts: (netid, hostid)
  - netid identifies a network
  - hostid identifies a host on that network

- Example: linux-1.ece.iastate.edu

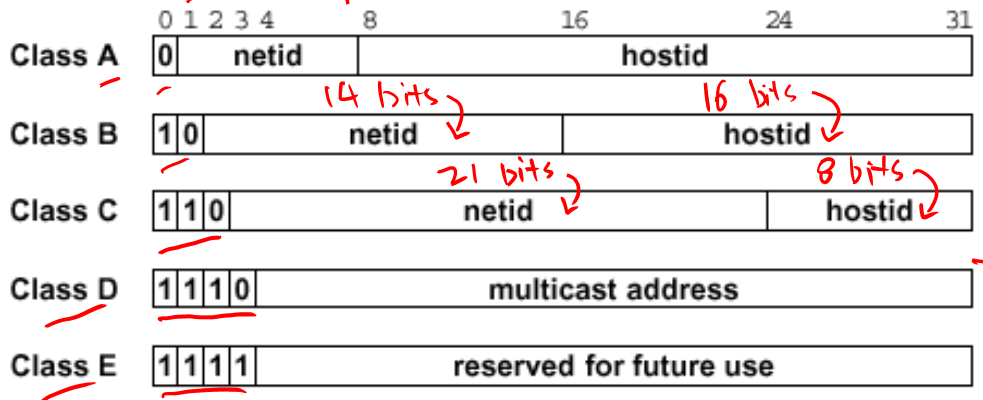
  129.186.205.13 ✓

  10000001 10111010 11001101 00001101 ✓

  10 = 14 bits

Class-B

Classful Addressing Scheme



$\leq 2^{14}$ Class-B networks
$\leq 2^{16}$ IP addresses per class-B net

7 bits

14 bits

16 bits

21 bits

8 bits

$\leq 2^{21}$ Class-C networks
$\leq 2^{8} = 256$ IP addresses per class-C network

Example

205.100.1.5

11001101 01100100 00000001 00000101

netid | host id

Class-C

128.255.0.1 } U. Iowa

Class-B

134.161.0.1 } UNI

Class-B

Network Address

- IP addresses with all 0s or all 1s in the netid and/or hostid parts have special meanings and are reserved

- IP addresses can be used to refer to networks as well as individual hosts
  - By convention, an address that has all bits of the hostid equal to 0 is reserved to refer to the network
  - network address = IP address AND network mask
  - Slash notation of the network mask

bit-wise

11111111 11111111 00000000 00000000 ✓

255 . 255 . 0 . 0 ✓

/16

Example

⇒ 129.186.205.13

AND

255.255.0.0

=

129.186.0.0/16

205.100.1.5

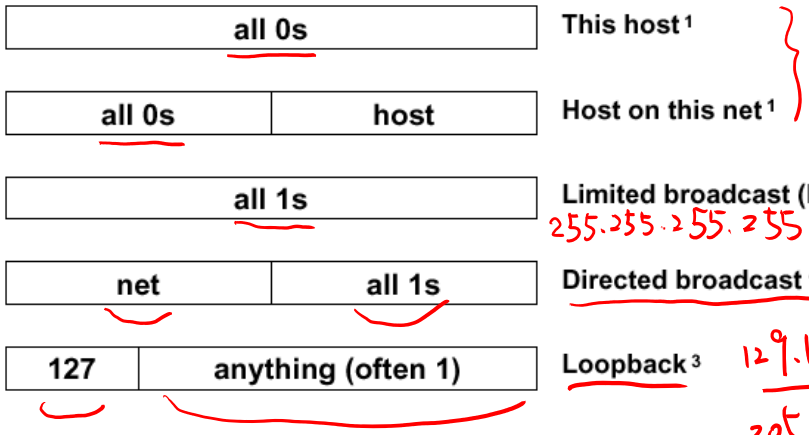
AND

255.255.255.0

=

205.100.1.0/24

Reserved IP Addresses



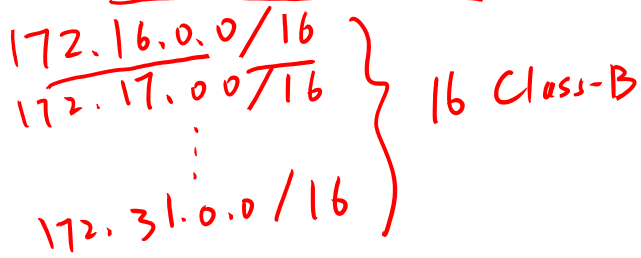
Notes: [1] Allowed only at system startup and is never a valid destination address.
[2] Never a valid source address.
[3] Should never appear on a network.

Private IP Addresses

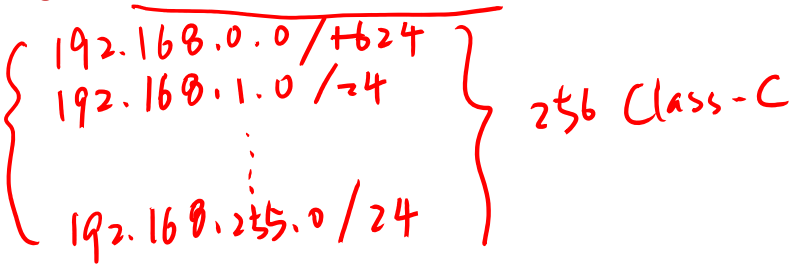
- Specific ranges of IP addresses for private networks
  - Use is restricted to private internets that do not connect directly to the Internet
  - These addresses are considered unregistered, and routers in public Internet discard packets with these addresses
  - Range 1: 10.0.0.0 --- 10.255.255.255

Private IP Addresses

- Specific ranges of IP addresses for private networks
  - Range 2: 172.16.0.0 --- 172.31.255.255



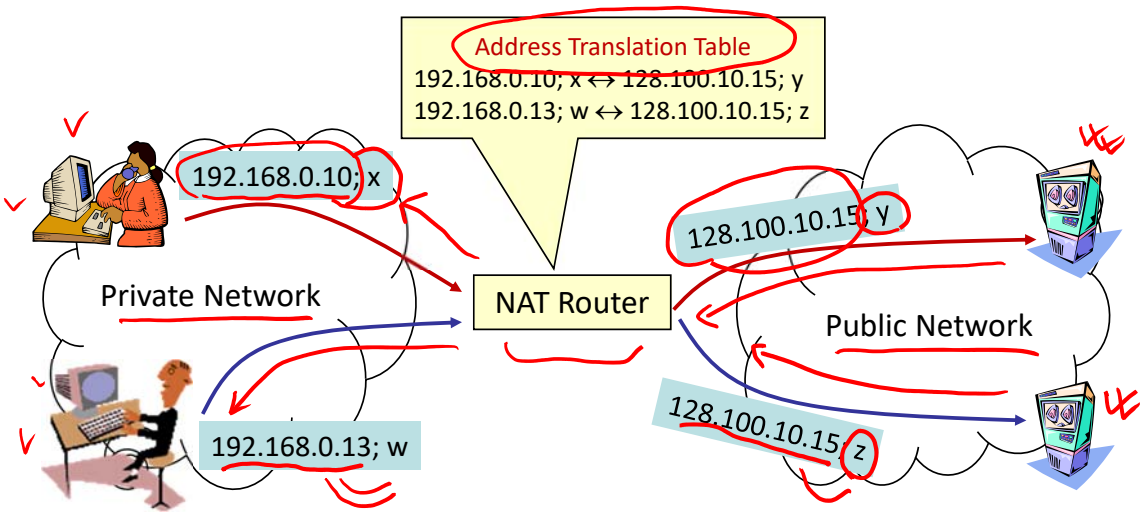
  - Range 3: 192.168.0.0 --- 192.168.255.255 Class-C



NAT Operation

- NAT (Network Address Translation) is used to convert between private & global IP addresses
  - Hosts inside private networks generate packets with private IP address & TCP/UDP port number
  - NAT maps each private IP address & port number into shared global IP address & available port number
  - Address Translation Table allows packets to be forwarded unambiguously

NAT Operation



Summary

IP addresses that cannot be used to represent an individual host in public domain:

- Class D, class E
- network addresses
- reserved addresses
- private addresses

Example

233.87.5.67 (NO)

11101001

Class-D

155.100.1.255 (YES)

10010110 01100100 00000001 11111111

Class-B net id host id

Routing Table

- IP layer in each host and router maintains a routing table

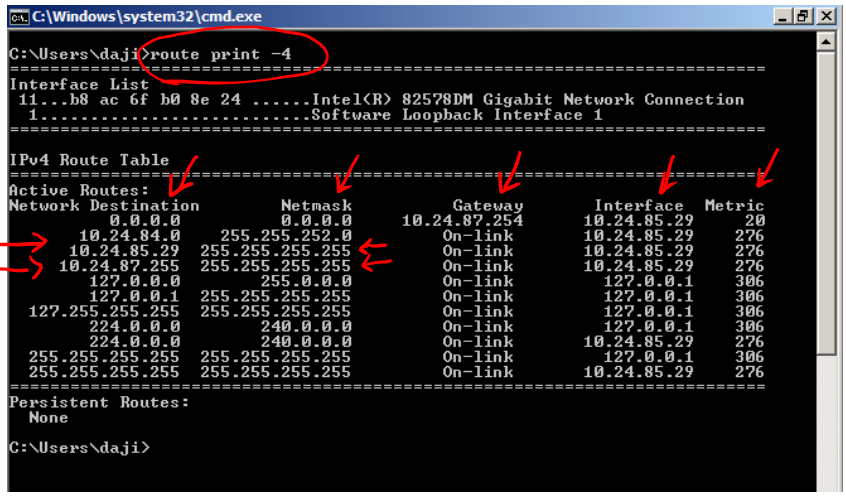
Destination	Network Mask	Next-hop Router	Network Interface	… …
…	…	…	…	… …
…	…	…	…	… …

metric

255.255.255.255 /32 → destination host

Routing Table

" route print -4 "



Routing Table

- Routing table is searched in the following order:
  1. Whether the destination IP address appears in one of the table entries
  2. Whether the destination network address appears in one of the table entries (with help of network mask)
  3. The default router entry
  4. If none of above searches is successful, declare packet undeliverable, send ICMP "Host Unreachable Error" packet back to the sender

/32

/24 /16

/0

Internet Control Message Protocol

destination IP address AND network mask

= destination network address

0.0.0.0/0

Routing Table: Example

#1	129.186.205.13/32	129.186.205.13	Int #1
#2	129.186.0.0/16	129.186.0.1	Int #1
#3	0.0.0.0/0	129.187.0.1	Int #2

Longest prefix first

Packet with destination IP address of:

① 129.186.205.13 ⇒ match entry #1, #2, #3

② 129.186.200.3 AND "/16" ⇒ match entry #2
= 129.186.0.0

③ 129.168.33.44 ⇒ match with entry #3
AND "/0"
= 0.0.0.0

④ 192.168.33.44
Private IP address
⇒ discard