# Data Delivery

CIS 68C2-01

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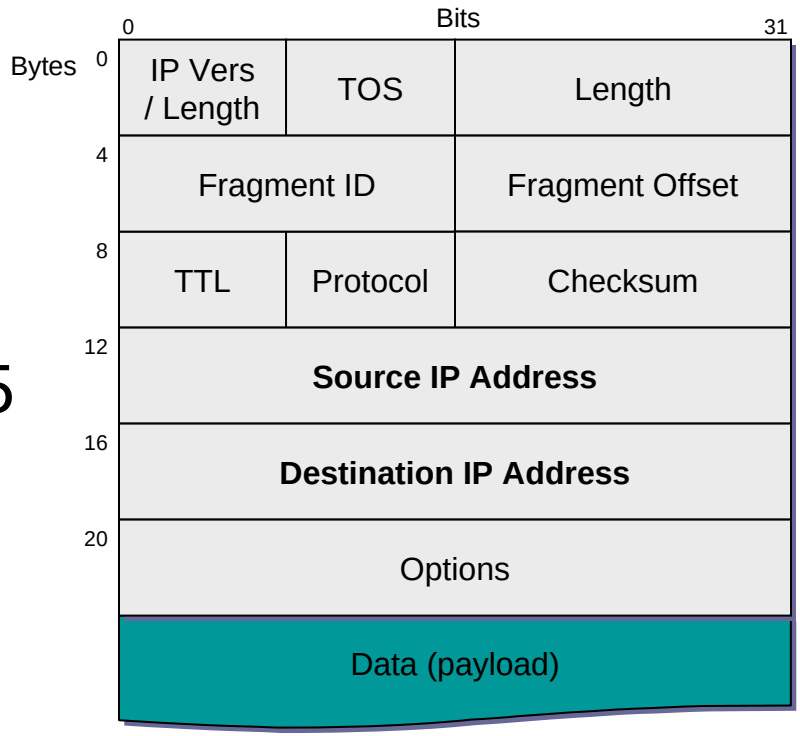
# Data Delivery

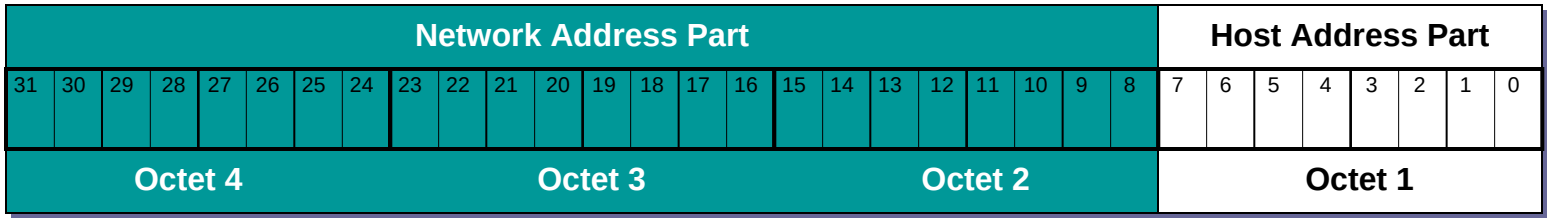
- Addressing
  - Determines destination host
- Routing
  - How data is delivered to other networks
- Multiplexing
  - How data is delivered to software within a host

# Addressing

- The IP Address
  - Always 32 bits
    - Not byte-oriented
  - IP Datagram words 4 & 5
  - Comprised of two parts
    - Network Address part
    - Host Address part




IP Datagram



# Addressing

- Three Forms of Addressing
  - Unicast
    - Packets are targeted to a single interface
      - IP datagram's Destination Address is interface's IP address
  - Broadcast
    - Packets are targeted to all interfaces attached to the network
    - Broadcast packets are not transmitted across routers
  - Multicast
    - Frame targeted to only *subscribed* interfaces
      - An interface must be programmed to receive a given multicast address
    - Routers may forward, if support multicast and requested

# Addressing

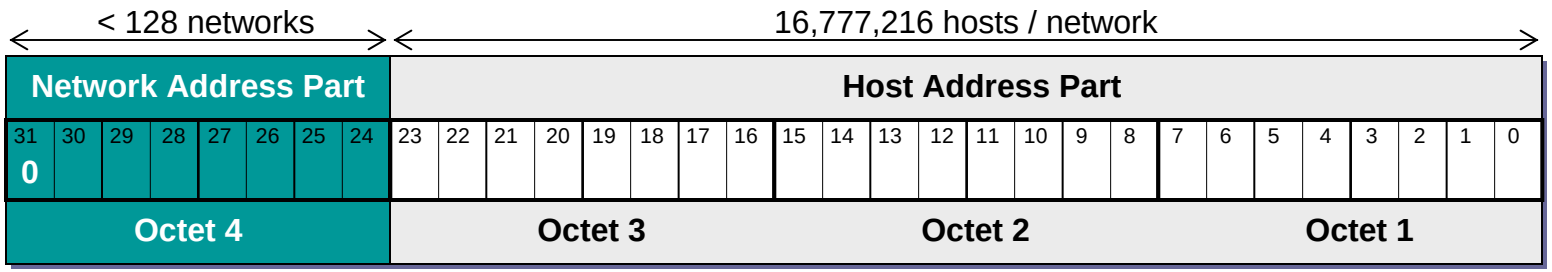
- Multi-homing
  - A system with multiple interfaces
  - IP Addresses are
    - Individually assigned to each NIC
    - Really interface addresses, not *host* addresses
      - The term *host address* is commonly used, but *interface address* is more correct
  - Consider routing system on two networks, A & B
    - Known by one IP address on network A, but by another IP address on network B

# Addressing - Classes

- Traditional IP Address Classes
  - IP addresses are traditionally divided into *classes*
    - Class A
    - Class B
    - Class C
    - Multicast
  - The class defines
    - The range of valid IP addresses
    - The maximum number of hosts possible on a network

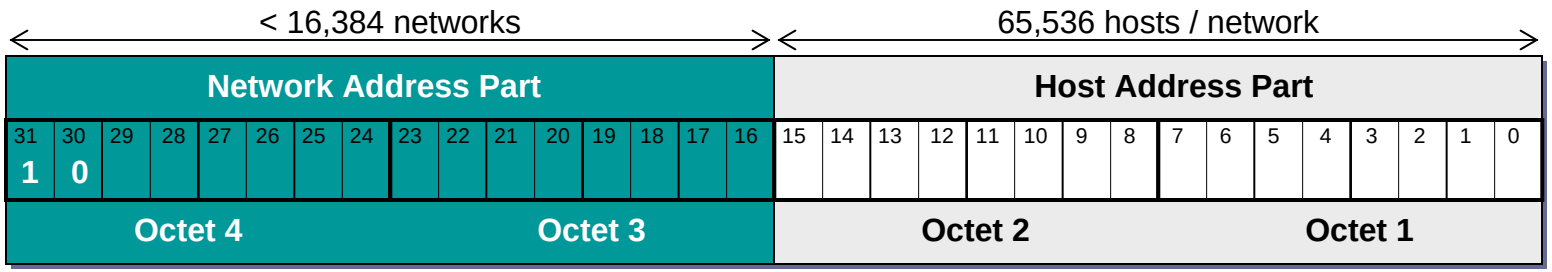
# Addressing - Classes

- Class A Addresses
  - Network address part is the first 8 bits
    - Bit 31 of IP address is 0
  - Host address part is the last 24 bits
  - IP addresses from 1.x.x.x to 127.x.x.x
  - Number of networks: < 128 ($2^7$)
  - Maximum hosts/network: 16,777,216 ($2^{24}$)



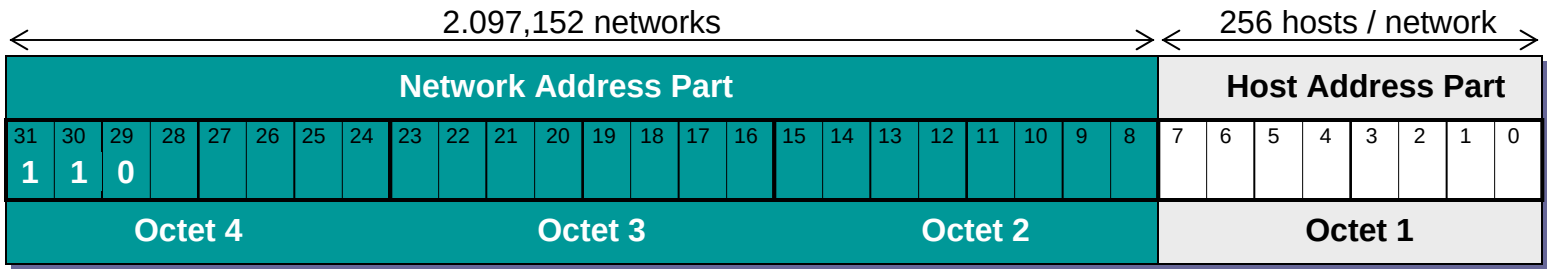
# Addressing - Classes

- Class B Addresses
  - Network address part is the first 16 bits
    - Bits 31-30 of IP address is 1 0
  - Host address part is the last 16 bits
  - IP addresses from 128.x.x.x to 191.x.x.x
  - Number of networks: < 16,384 ($2^{14}$)
  - Maximum hosts/network: 65,536 ($2^{16}$)



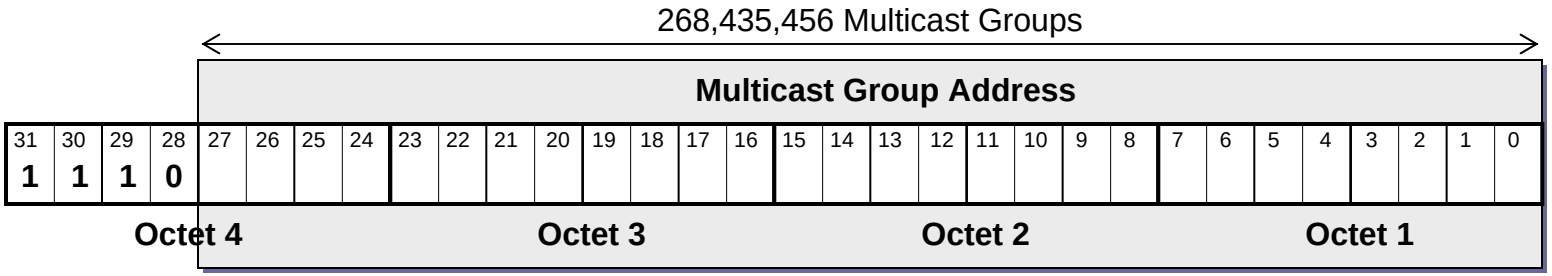
# Addressing - Classes

- Class C Addresses
  - Network address part is the first 24 bits
    - Bits 31-29 of IP address is 1 1 0
  - Host address part is the last 8 bits
  - IP addresses from 192.x.x.x to 223.x.x.x
  - Number of networks: < 2,097,152 ($2^{21}$)
  - Maximum hosts/network: 256 ($2^{8}$)



# Addressing - Classes

- Multicast Addresses (*aka* Class D)
  - No network part
    - Bits 31-28 of IP address is 1 1 1 0
    - Entire address specifies multicast group
  - Multicast group address is last 28 bits
  - IP addresses from 224.x.x.x to 239.x.x.x
  - Number of multicast groups: < 268,435,456 ($2^{28}$)



# Addressing - Classes

- Problems with Address Classes
  - Class A
    - Too many hosts per network; too few networks
  - Class B
    - Enough hosts per network; too few networks
  - Class C
    - Provides plenty of networks; too few hosts per network
  - IP addresses were not distributed geographically
    - Creates routing inefficiencies and aggregating problems
      - Today, IP ranges are given to large ISPs

# Addressing - CIDR

- Classless Internet Domain Routing - CIDR
  - Flexible division between the network /host parts of an IP address
  - Temporary solution until IPv6 deprecates IPv4
  - Requires a network mask (netmask)
    - IP address-like mechanism to differentiate network part from host part
    - The netmask that corresponds to class A, B, or C addresses is called the default mask or natural mask
  - Required router & routing protocols modifications
    - CIDR unsupported in older operating systems and older routing protocols such as RIP

# Addressing - CIDR

- Specifying Network Addresses
  - IP address / network mask pair is cumbersome
  - Abbreviated notation
    - Specify the IP address followed by the number of bits used for the network part
      - IP-address/network-length
    - Example
      - 192.4.0.0/16
        - Netmask 255.255.0.0
      - 172.16.26.32/27
        - Netmask 255.255.255.224

# Addressing - CIDR

- Supernetting
  - Creating a network with more hosts than the traditional class address allows
  - For IP address range 195.4.0.x -> 195.4.255.x
    - As class C addresses, limited to
      - 256 networks, with 256 hosts/network
    - Supernetting allows more options:
      - 1 network; 65536 hosts/network
      - 2 networks; 32768 hosts/network
      - 16 networks; 4096 hosts/network
      - 128 networks; 512 hosts/network
      - etc...

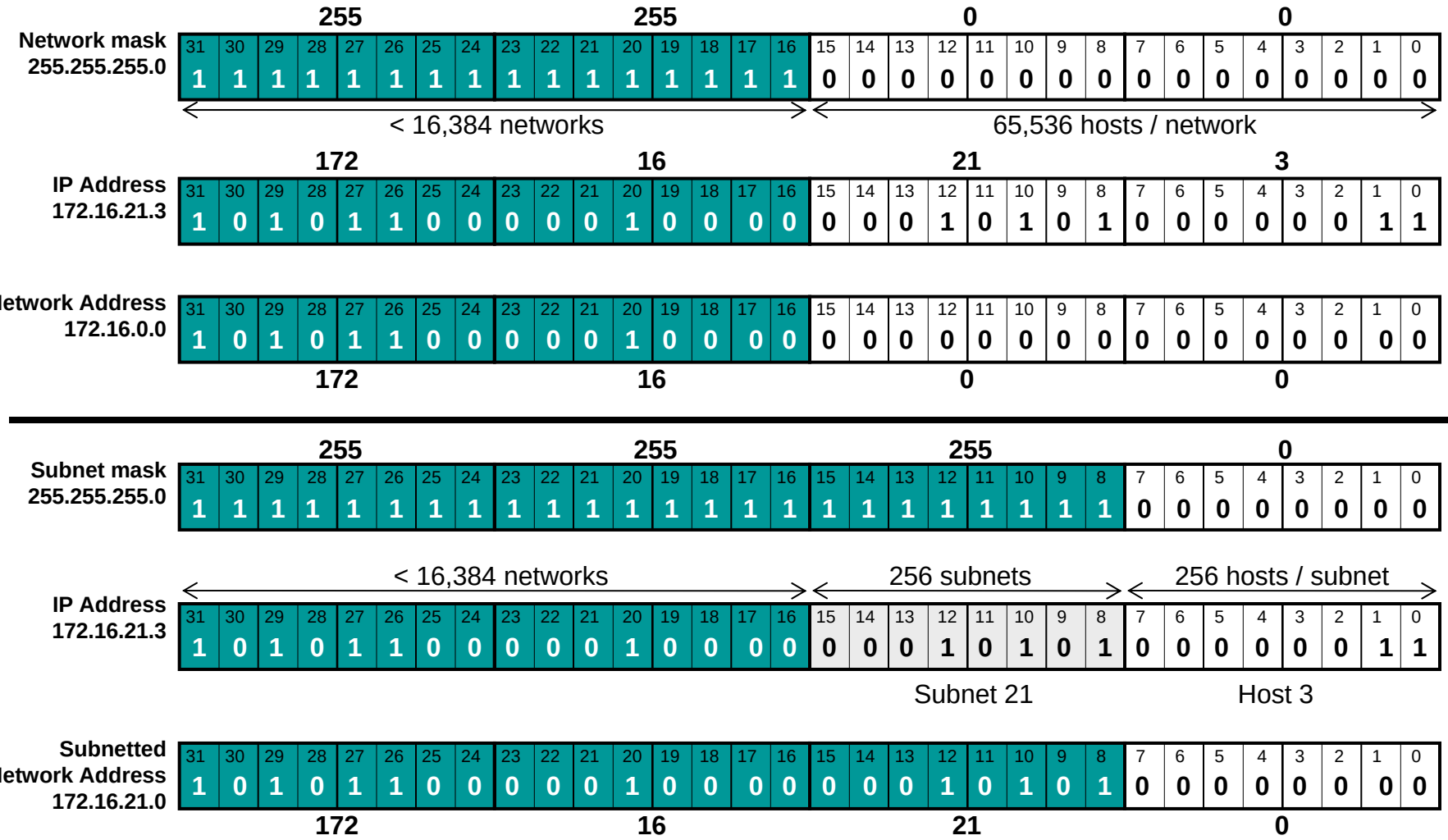
# Addressing - CIDR

- Subnetting
  - Subdivision of network address into independent networks
  - Used locally to increase the number of networks
    - Hence, also reduces the number of possible hosts
  - Allows departmental management of IP addresses
  - Allows routers to seemingly *join* networks
    - Routers must address two different networks
    - Overcomes distance limitations, or hardware differences
  - The *subnet mask* vs. *network mask*
    - Subnet mask is local, used internally within an organization
      - A **subnet mask** is used internally to specify network address part
    - Network mask is used externally

# Addressing - CIDR

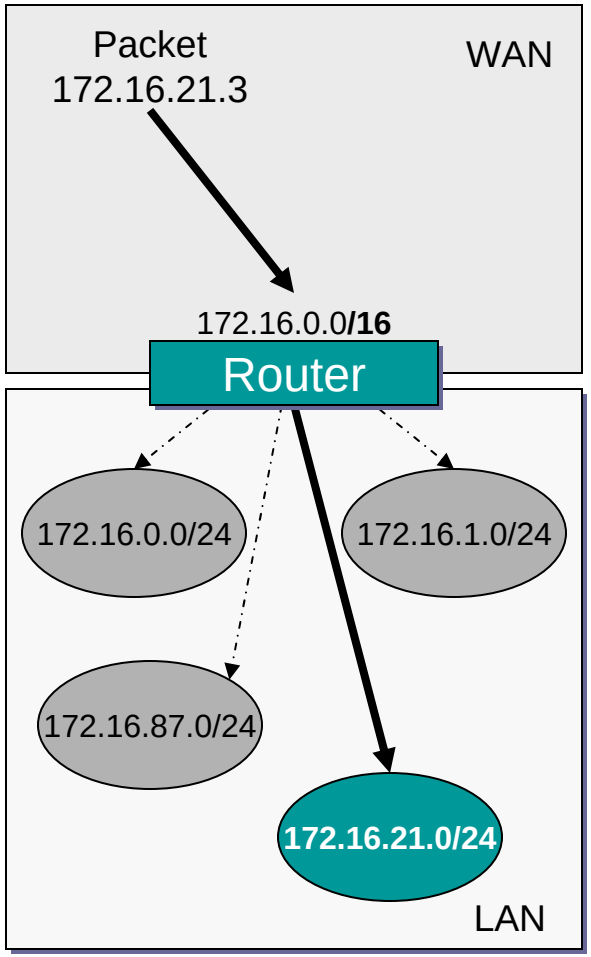
- Subnetting
  - Example
    - IP Address: 172.16.21.3/16
    - Class B
    - Natural network mask is 255.255.0.0
      - Allows up to 65536 hosts
    - Using subnet mask of 255.255.255.0
      - Reduces number of hosts/network to 256
      - Provides 256 subnetted networks
      - Routers are used to route traffic from one subnet to another

# Addressing - CIDR



# Addressing - CIDR

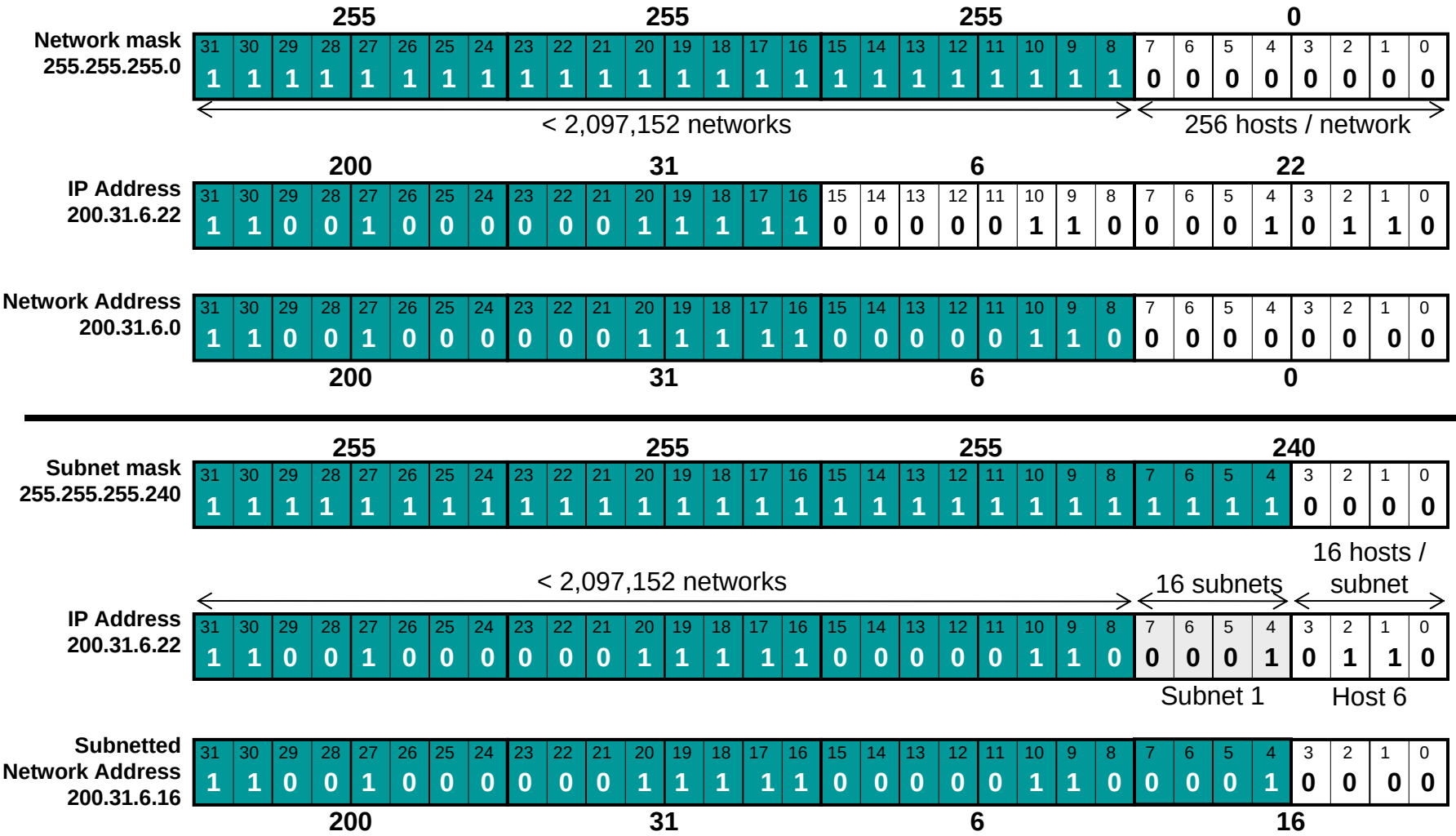
- Subnetting
  - IP Address 172.16.21.3
  - On WAN
    - Appears as host number x.x.**21.3** on network **172.16**.0.0/16
  - Within LAN
    - Packet is routed to subnetted network 172.16.**21**.x
      - Host 3 receives packet
      - Subnet mask of 255.255.255.0



# Addressing - CIDR

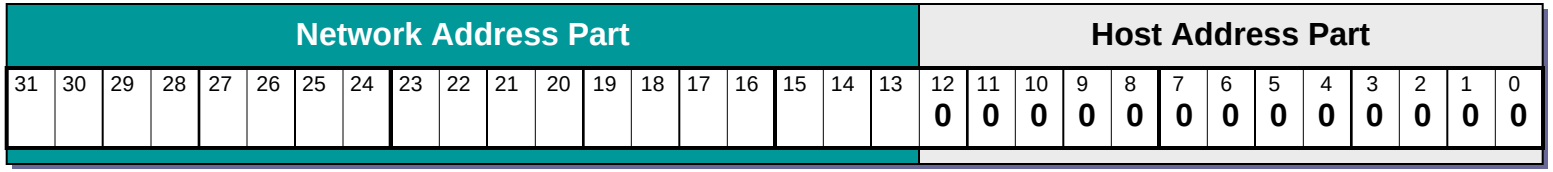
- Subnetting
  - Example
    - IP Address: 200.31.6.22
    - Class C
    - Natural network mask is 255.255.255.0
      - Allows up to 256 hosts
    - Using subnet mask of 255.255.255.240
      - Reduces number of hosts/network to 16
        - Only 4 bits now for the host part
      - Provides 16 subnetted networks
        - 4 extra bits for the network part

# Addressing - CIDR

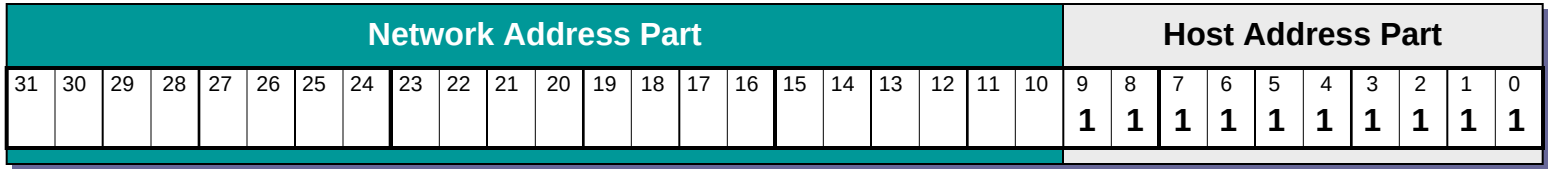


# Addressing – Reserved IPs

- Reserved Host Numbers
  - All 0's host part of IP address
    - Refers to the **network** itself
    - Used by routers and routing software




  - All 1's host part of IP address
    - Is the **broadcast** address for the network



# Addressing – Reserved IPs

- Reserved Network Numbers
  - 0.0.0.0 (Class A)
    - The *default* route, used to simplify routing
  - 127.0.0.0 (Class A)
    - The *loopback* network address
    - Simplifies programming network applications
  - 223.x.x.x to 239.x.x.x (Multicast)
  - 240.x.x.x to 255.x.x.x are reserved

# Addressing – Private IPs

- Addresses for Private Internets
  - Class A: 10.0.0.0
  - Class B: 172.16.0.0 to 172.31.255.255
  - Class C: 192.168.0.0 to 192.168.255.255
  - For use in private internets only
    - Requires no coordination with in Internet registry
  - Must not be connected outside the *enterprise*
    - These systems cannot connect directly to the Internet
  - Reduces demands on limited IP address pool
  - See also: RFC 1918

# Routing

- Routing
  - How do packets find their way?
    - Hosts only send packets to hosts on the same network
  - Old way - Hierarchical System
    - The Core – the central system
    - Subordinate Core Gateways
      - Each contained all information about internet
    - Gateway to Gateway Protocol (GGP)
    - Major Weakness
      - All routes processed by the Core!

# Routing

- New model
  - Routing Domains
    - Non-hierarchical
      - Central Core system not required for best routes
    - Collections of co-equal, autonomous systems
    - Border Gateway Protocol (BGP)
      - Protocol used to exchange routing information
    - Problem still remains – who decides best routes?

# Routing

- Determining Best Routes
  - Now obsolete NSFNET employed
    - Policy routing database (PRDB)
    - Exchanged reachability information
  - Newer method
    - Network Access Points (NAPs)
      - Each has Routing Arbiter (RA) server
      - Provides access to the Routing Arbiter database (RADB)
      - Allows ISPs to validate reachability information provided by autonomous systems

# Routing

- Internet Routing Registry (IRR)
  - RADB is only one part
  - Multiple organizations validate and register routing information
    - RIPE NCC
      - Reseaux IP Europeens Network Control Center
      - Routing registry information for Europe
    - MCI, ANS, etc.
    - All use common RIPE-181 standard to share info

# Routing

- Routing Table
  - All IP network devices make routing decisions
    - For hosts, decision is simple
      - Local network packets are addressed to local host
      - Packets destined for other networks are addressed to the local gateway
    - Recall this occurs at IP level
      - Routing decision based on network part of IP address
        - Network part determined from the network mask
      - If packet is for local network
        - Either the subnet mask or default mask is used to determine destination network

# Routing

- Routing Table
  - Also called the **forwarding table**
  - Every IP device has a routing table
  - Tells IP where to deliver packets
    - Uses network number to look up routes in table
    - Assigns packet's destination IP address
  - Entries in table
    - Are considered routes to other networks
    - Can be created dynamically or statically
  - Routing is just a table lookup!

# Routing

- Routing Table
  - The **netstat** utility shows a host's routing table
    - Flags: U = up; G = gateway; H = host
    - Gateway: means *goes through given interface*
    - Ref: number of active uses of route (eg. by TCP)
    - Use: number of packets sent through route

```
$ netstat -rn

Routing Table:
  Destination           Gateway           Flags  Ref   Use   Interface
-------------------- -------------------- ----- ----- ------ ---------
153.18.0.0           153.18.75.207         U         3    186  elx0
224.0.0.0            153.18.75.207         U         3      0  elx0
default              153.18.75.254         UG        0    140
127.0.0.1            127.0.0.1             UH        0   6877  lo0
```

# Address Resolution

- The problem
  - Physical networks are unaware of IP addresses
- The Solution
  - Map IP addrs to physical hardware addresses
  - Performed by TCP/IPs Network Access layer
  - Address Resolution Protocol (ARP)
    - Performs IP to Ethernet translation
    - Maintains dynamic table of IP/Ethernet pairs

# Address Resolution

- ARP
  - Requests are made to translate IP addresses
  - ARP looks in its ARP Table
    - If IP address is found, Ethernet address is returned
    - If not found, ARP broadcasts request to network
      - Receiving host then returns its Ethernet address
      - IP/Ethernet address pair is cached in ARP table for future
  - ARP Requests
    - Only published addresses are returned
      - A host normally publishes and returns its own Ethernet address
      - A host may return Ethernet address for other hosts
        - Called Proxy ARP

# Address Resolution

- Proxy ARP
  - Allows servers to respond for remote hosts that may not be able to respond
    - Server responds with its own Ethernet address
    - Packets destined for remote host are sent to server
    - Server forwards packets to remote host in proxy
      - Proxy means – to act on another's behalf

# Address Resolution

- The arp command shows the ARP table
  - Flags: p = Publish; s = Static; m = Mapping

```
$ arp taipei
taipei (153.18.75.207) at 0:10:4b:35:7e:18 permanent published
$ arp -a
Net to Media Table
Device   IP Address                  Mask      Flags   Phys Addr
------ --------------------     --------------- ----- ---------------
elx0   losaltos                 255.255.255.255       00:10:4b:21:00:c1
elx0   153.18.75.254            255.255.255.255       00:10:f6:ac:58:00
elx0   tiptoe.fhda.edu          255.255.255.255       00:00:0c:45:bb:32
elx0   taipei                   255.255.255.255 SP    00:10:4b:35:7e:18
elx0   153.18.71.251            255.255.255.255       00:00:0c:45:bb:32
elx0   153.18.82.12             255.255.255.255       00:04:ac:49:d5:95
elx0   BASE-ADDRESS.MCAST.NET   240.0.0.0       SM    01:00:5e:00:00:00
```

# Multiplexing

- Protocols Numbers
  - Which protocol above IP receives packet
    - UPD, TCP, etc.
    - 3rd word of IP datagram
    - /etc/protocols

```
# Internet (IP) protocols
#
ip              0       IP              # internet protocol
icmp            1       ICMP            # internet control message protocol
ggp             3       GGP             # gateway-gateway protocol
tcp             6       TCP             # transmission control protocol
egp             8       EGP             # exterior gateway protocol
pup             12      PUP             # PARC universal packet protocol
udp             17      UDP             # user datagram protocol
```

# Multiplexing

- Port Numbers
  - Allows routing data within the destination host
    - to a specific network service or application process
      - E.g. FTP, HTTP, etc.
    - Source and Destination ports
      - 1st word of TCP segment or UDP message
  - Port numbers are listed in the /etc/services table

# Multiplexing

- /etc/services
  - Table of port numbers / protocols / service names
  - Reserved Ports numbers
    - Less than 256 are for Well-known services such as FTP, telnet, http
      - Well-known ports simply connection process
    - 256 – 1024 were originally UNIX-specific services such as rlogin, lpr, etc.
      - No longer UNIX-specific

# Multiplexing

- /etc/services

```
# Network services, Internet style
#
tcpmux          1/tcp
systat          11/tcp          users
daytime         13/tcp
daytime         13/udp
netstat         15/tcp
chargen         19/tcp          ttytst source
chargen         19/udp          ttytst source
ftp-data        20/tcp
ftp             21/tcp
telnet          23/tcp
smtp            25/tcp          mail
time            37/tcp          timserver
time            37/udp          timserver
http            80/tcp          httpd
```

# Multiplexing

- Port Numbers
  - Protocols (TCP, UDP) share the same port numbers for services
  - The pair of protocol and port number identifies the target application or network service
  - See picture on page 45

# Multiplexing

- Portmapper
  - Multiplexes Remote Procedure Call (RPC) services at port 111
  - Eliminates need for using well-known port
  - /etc/rpc

```
rpcbind         100000  portmap sunrpc rpcbind
rstatd          100001  rstat rup perfmeter
rusersd         100002  rusers
nfs             100003  nfsprog
ypserv          100004  ypprog
mountd          100005  mount showmount
ypbind          100007
walld           100008  rwall shutdown
yppasswdd       100009  yppasswd
```

# Multiplexing

- Sockets
  - Well-known ports numbers
    - Used to initiate the connection to a service
  - Dynamically-allocated port numbers
    - Allows concurrent users on same Well-know port
      - Source port is dynamically allocated
      - Destination port is Well-known port
  - The IP addr / port number is a Socket
  - Pair of sockets is unique in Internet