The Internet Protocol

- **IP datagram format**

- **IP addressing**

Note: Many of the lecture slides are based on presentations that accompany *Computer Networking: A Top Down Approach,* 6th edition, by Jim Kurose & Keith Ross, Addison-Wesley, 2013.

The Internet Protocol (IP)

- IP is the internet's network layer protocol
  - alternatives: few, obscure

- IP accepts TCP / UDP segments, destination address
  - <u>Encapsulates</u> segment, source address, destination address, other info … into datagram
  - Provides "best-effort", host-to-host delivery

IP datagram header

- VER - version of IP (currently 4)
- HEAD. LEN - header length (number of 32-bit "lines")
- SERVICE TYPE - sender's preference for low latency, high reliability
- LENGTH - total bytes in datagram (including header)
- IDENT, FLAGS, FRAG OFFSET - used with fragmentation (later)
- TTL - *time to live*
  - decremented in each router
  - datagram discarded when TTL = 0
- UPPER LAYER - type of protocol carried in datagram
  - e.g., TCP, UDP
- HEADER CHECKSUM - 1s-complement of sum
- SOURCE IP ADDRESS - IP address of *original* source
- DESTINATION IP ADDRESS - IP address of *ultimate* destination
- OPTIONS – added in multiples of 32 bits (padded if necessary)
  - e.g., record route, timestamp
  - If no options, HEAD LEN = 5

- DATA – TCP or UDP segment (includes segment header)

Datagram overhead
At least:
20 bytes of TCP/UDP
20 bytes of IP
= 40 bytes for every packet

ver	head. len	service type	length	
16-bit identifier			flgs	fragment offset
time to live		upper layer	header checksum	
32 bit source IP address				
32 bit destination IP address				
Options (if any)				
data (variable length, typically a TCP or UDP segment)				

Datagram forwarding

- IP header contains all information needed to deliver datagram to destination computer
  - Destination address
  - Source address
  - Identifier (session, sequence)
  - Other delivery information
- Each router examines header of each datagram and forwards datagram along path to destination

- A key aspect of a virtual network is a single, uniform address format
  - Address format must be independent of any particular hardware address format
    - Can't use hardware addresses because different technologies have different address formats
    - Can't use addresses that are local to a network because multiple networks might use the same addresses internally

- In IPv4, each host is assigned a 32-bit number, called the *IP address* or *Internet address*
  - Unique across entire Internet
  - Number of unique IP addresses possible:
    - 2^{32} = 4,294,967,296
    - some are reserved

- IP version 6 (later)

IP address notation

- Common form is "dotted decimal"
- e.g.: 128.253.40.28
- range is [0.0.0.0 … 255.255.255.255]
  - each "component" range is [0 … 255]

- IP address is just a 32-bit number
- It's the same internally, regardless of its external representation
- Dotted-decimal is only for convenience
- In hexadecimal form, the range is [00000000 … FFFFFFFF]
  - divides naturally into 4 bytes (1 byte = 2 hex digits)
  - e.g.:   128.253.40.28 (D-D) = 80 FD 28 1C (hex)
  - each group represents one byte [00 … FF]
- In binary form, the range is [00000000000000000000000000000000 … 11111111111111111111111111111111]
  - e.g.:   128.253.40.28 (D-D) = 10000000 11111101 00101000 00011100 (binary)
- In ordinary decimal form, the range is [0 … 4294967295]
  - e.g.:   128.253.40.28 (D-D) = 2164074524 (decimal)

IP address hierarchy

- Every ISP <u>network</u> in the internet is assigned *network address* that is unique *within the internet*
  - includes indicator for number of bits used for network identification
  - may be divided into sub-nets
  - e.g.,   128.193.35.0 / 24
- Every <u>host</u> in a specific network is assigned a *host number* that is unique *within that network*
  - e.g.,   0.0.0.123
- Host's *IP address* is the combination of the network address and host address
  - e.g.,   128.193.35.123 / 24
- Address format enables efficient routing
  - longest prefix matching

IP address assignment

- ISP network addresses are unique
  - assigned by ICANN:
    - Internet Corporation for Assigned Names and Numbers
- Host addresses may be duplicated on different networks
  - assigned by network (admin or DHCP)
- The combination of network address and host number is unique in the entire internet
  - assignment of ISP network addresses must be coordinated globally
  - assignment of sub-nets and host numbers can be managed locally

- IP datagram
  - format
  - contents
- IP addresses
  - formats, conversions
    - e.g., dotted-decimal to binary
  - network address, host number