

# Internet Protocol

Raj Jain  
Washington University  
Saint Louis, MO 63131  
Jain@cse.wustl.edu

These slides are available on-line at:

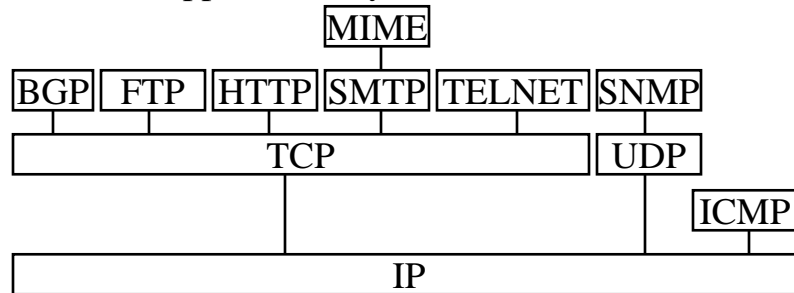
<http://www.cse.wustl.edu/~jain/cse473-05/>



- Internetworking Terms
- IP Header
- Fragmentation and Re-assembly
- IP Addressing, Subnetting, Private Addresses
- Address Resolution Protocol (ARP)
- Internet Control Message Protocol (ICMP)

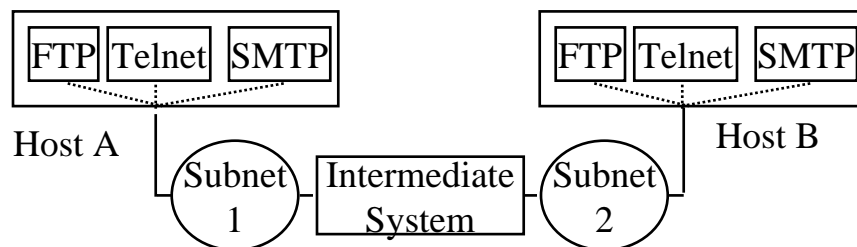
## TCP/IP Protocols

- ❑ Network access layer: Ethernet, Token Ring
- ❑ Internet layer: IP
- ❑ Host-host layer: TCP, UDP
- ❑ Process/application layer: FTP, Telnet, Mail (SMTP)



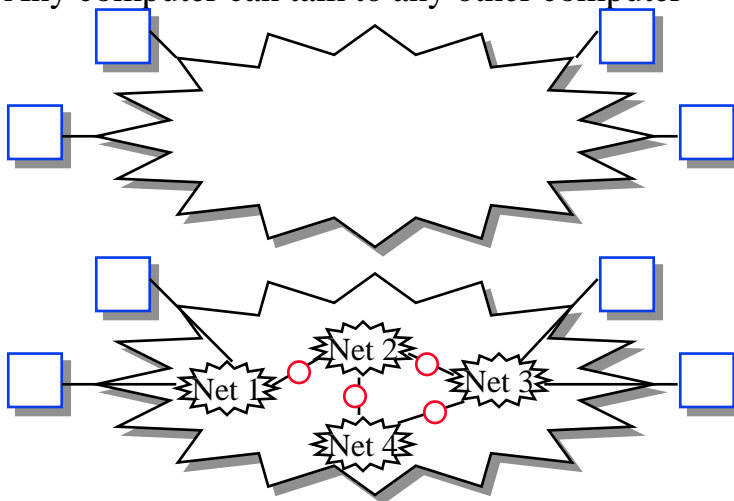
## Internetworking Terms

- ❑ End-system: Host
- ❑ Network: Provides data transfer between end-systems
- ❑ Internet: A collection of networks
- ❑ Subnetwork: Each component of an internet
- ❑ Intermediate System: Connects two subnetworks



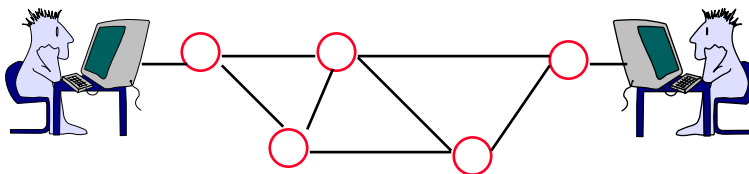
## Internet = Collection of Networks

- Any computer can talk to any other computer



## Internet Protocol (IP)

- Layer 3 protocol that *forwards* datagrams across internet
- Uses routing tables prepared by routing protocols, e.g., Open Shortest Path First (OSPF), Routing Information Protocol (RIP)
- Connectionless service vs connection-oriented (circuits)



## IP Header

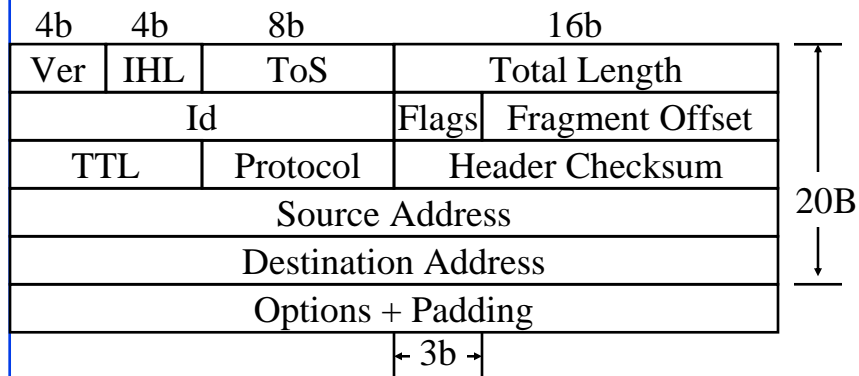


Fig 16.7

## IP Header (Cont)

- ❑ Version (4 bits)
- ❑ Internet header length (4 bits): in 32-bit words. Min header is 5 words or 20 bytes.
- ❑ Type of service (8 bits): Reliability, precedence, delay, and throughput
- ❑ Total length (16 bits): header+data in bytes
- ❑ Identifier (16 bits): Helps uniquely identify the datagram during its life for a given source, destination address

## IP Header (Cont)

- ❑ Flags (3 bits):
  - ❑ More flag - used for fragmentation
  - ❑ No-fragmentation
  - ❑ Reserved
- ❑ Fragment offset (13 bits): In units of 8 bytes
- ❑ Time to live (8 bits): Specified in router hops
- ❑ Protocol (8 bits): Next level protocol to receive the data
- ❑ Header checksum (16 bits): 1's complement sum of all 16-bit words in the header

## IP Header (Cont)

- ❑ Source Address (32 bits)
- ❑ Destination Address (32 bits)
- ❑ Options (variable): Security, source route, record route, stream id (used for voice) for reserved resources, timestamp recording
- ❑ Padding (variable):
  - Makes header length a multiple of 4
- ❑ Data (variable): Data + header  $\leq 65,535$  bytes

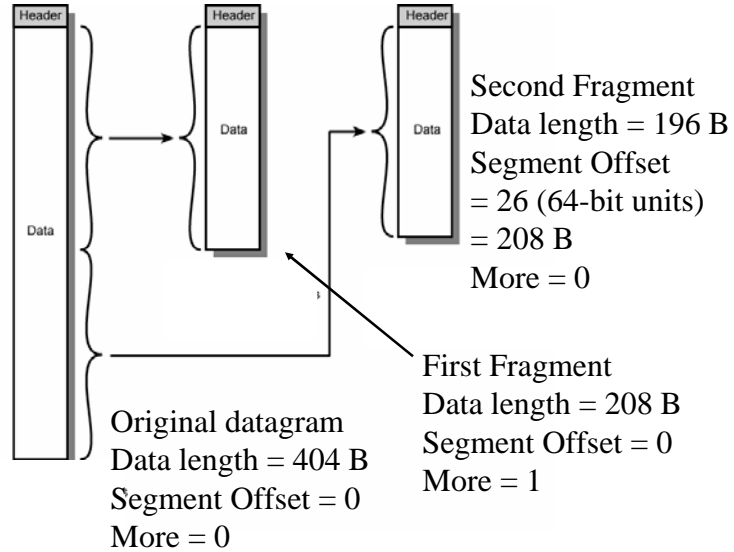
## Fragmentation and Re-assembly

- ❑ When to re-assemble?
  - ❑ At destination: Results in packets getting smaller as data traverses internet
  - ❑ Intermediate re-assembly
    - ❑ Need large buffers at routers
    - ❑ Buffers may fill with fragments
    - ❑ All fragments must go through same router
      - ◆ Inhibits dynamic routing
- ❑ IP re-assembles at destination only

## IP Fragmentation Fields

- ❑ Data Unit Identifier (ID)
  - ❑ Identifies end system originated datagram
    - ❑ Source and destination address
    - ❑ Protocol layer generating data (e.g. TCP)
    - ❑ Identification supplied by that layer
- ❑ Total length: Length of user data plus header in octets
- ❑ Data Offset - Position of fragment in original datagram
  - ❑ In multiples of 64 bits (8 octets)
- ❑ *More* flag
  - ❑ Indicates that this is not the last fragment

## Fragmentation Example

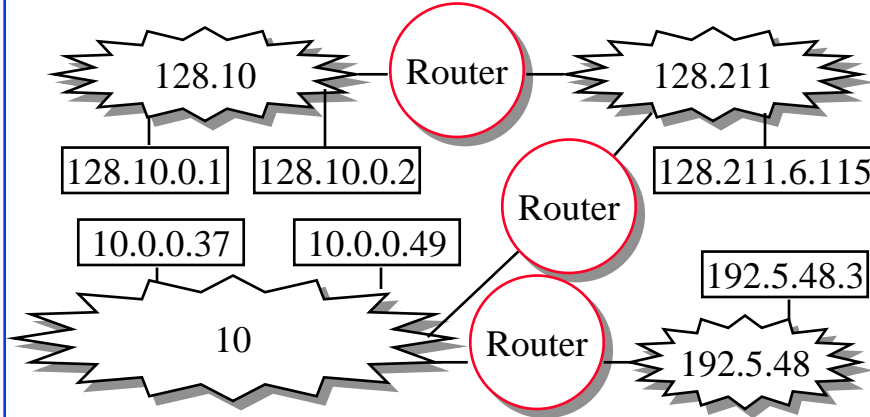


## IP Address

- |   |         |         |
|---|---------|---------|
| 0 | Network | Local   |
| 1 | 7       | 24 bits |
- |    |         |         |
|----|---------|---------|
| 10 | Network | Local   |
| 2  | 14      | 16 bits |
- |     |         |        |
|-----|---------|--------|
| 110 | Network | Local  |
| 3   | 21      | 8 bits |
- |      |                        |      |
|------|------------------------|------|
| 1110 | Host Group (Multicast) |      |
| 4    | 28                     | bits |
- |       |            |      |
|-------|------------|------|
| 11110 | Future use |      |
| 5     | 27         | bits |
- Local = Subnet + Host (Variable length)

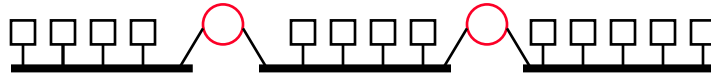


## IP Addressing

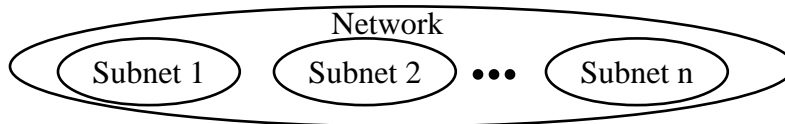


- ❑ All IP hosts have a 32-bit address. 128.10.0.1  
= 1000 0000 0000 1010 0000 0000 0000 0001
- ❑ All hosts on a network have the same network prefix

## Subnetting



- ❑ All hosts on a subnetwork have the same prefix.  
Position of the prefix is indicated by a “subnet mask”
- ❑ Example: First 23 bits = subnet  
 Address: 10010100 10101000 00010000 11110001  
 Mask: 11111111 11111111 11111110 00000000  
 .AND. 10010100 10101000 00010000 00000000



## Forwarding an IP Datagram

- ❑ Delivers **datagrams** to destination network (subnet)
- ❑ Routers maintain a “routing table” of “next hops”
- ❑ Next Hop field does not appear in the datagram



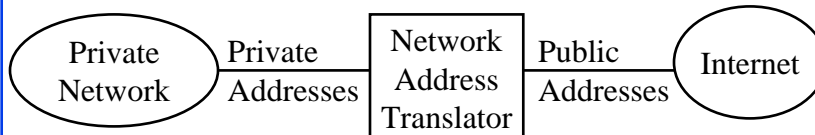
Table at R2:

Destination    Next Hop

Net 1	Forward to R1
Net 2	Deliver Direct
Net 3	Deliver Direct
Net 4	Forward to R3

## Private Addresses

- ❑ Any organization can use these inside their network  
Can't go on the internet. [RFC 1918]
- ❑ 10.0.0.0 - 10.255.255.255 (10/8 prefix)
- ❑ 172.16.0.0 - 172.31.255.255 (172.16/12 prefix)
- ❑ 192.168.0.0 - 192.168.255.255 (192.168/16 prefix)



## Address Resolution Protocol



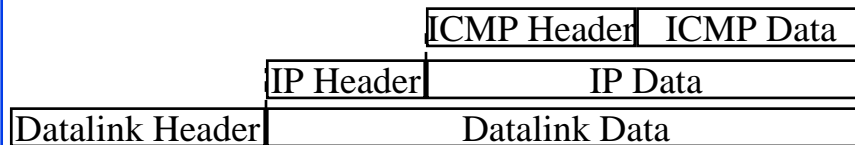
- ❑ Problem: Given an IP address find the MAC address
- ❑ Solution: Address resolution protocol
- ❑ The host broadcasts a request:  
“What is the MAC address of 127.123.115.08?”
- ❑ The host whose IP address is 127.123.115.08 replies back:  
“The MAC address for 127.123.115.08 is  
8A-5F-3C-23-45-5616”
- ❑ A router may act as a proxy for many IP addresses

## Internet Control Message Protocol (ICMP)

- ❑ Required companion to IP.  
Provides feedback from the network.
  - ❑ Destination unreachable
  - ❑ Time exceeded
  - ❑ Parameter problem
  - ❑ Source quench
  - ❑ Redirect
  - ❑ Echo
  - Echo reply
  - Timestamp
  - Timestamp reply
  - Information Request
  - Information reply

## Internet Control Message Protocol (ICMP)

- ❑ Required companion to IP. Provides feedback from the network.
- ❑ ICMP: Used by IP to send error and control messages
- ❑ ICMP uses IP to send its messages (Not UDP)
- ❑ ICMP does not report errors on ICMP messages.
- ❑ ICMP reports error only on the first fragment



## ICMP Message Format

IP Header	
Type of Message	8b
Error Code	8b
Checksum	16b
Parameters, if any	Var
Information	Var

## ICMP: Message Types

Type	Message
0	Echo reply
3	Destination unreachable
4	Source quench
5	Redirect
8	Echo request
11	Time exceeded
12	Parameter unintelligible
13	Time-stamp request
14	Time-stamp reply
15	Information request
16	Information reply
17	Address mask request
18	Address mask reply

## ICMP Messages

- ❑ Source Quench: Please slow down! I just dropped one of your datagrams.
- ❑ Time Exceeded: Time to live field in one of your packets became zero.” or “Reassembly timer expired at the destination.
- ❑ Fragmentation Required: Datagram was longer than MTU and “No Fragment bit” was set.
- ❑ Address Mask Request/Reply: What is the subnet mask on this net? Replied by “Address mask agent”

## Summary



- Hosts, networks, subnetwork, Internet
- IP: header
- Time to Live
- IP Addresses, Class A, B, C, D, Private, Subnet Mask
- Fragmentation
- ARP, ICMP

## Reading Assignment

- Read Sections 18.1-18.4 of Stallings' 7th edition

## Homework

- Submit answer to Exercise 18.5 from Stallings' 7<sup>th</sup> edition