# Internet Protocol

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These slides are available on-line at:
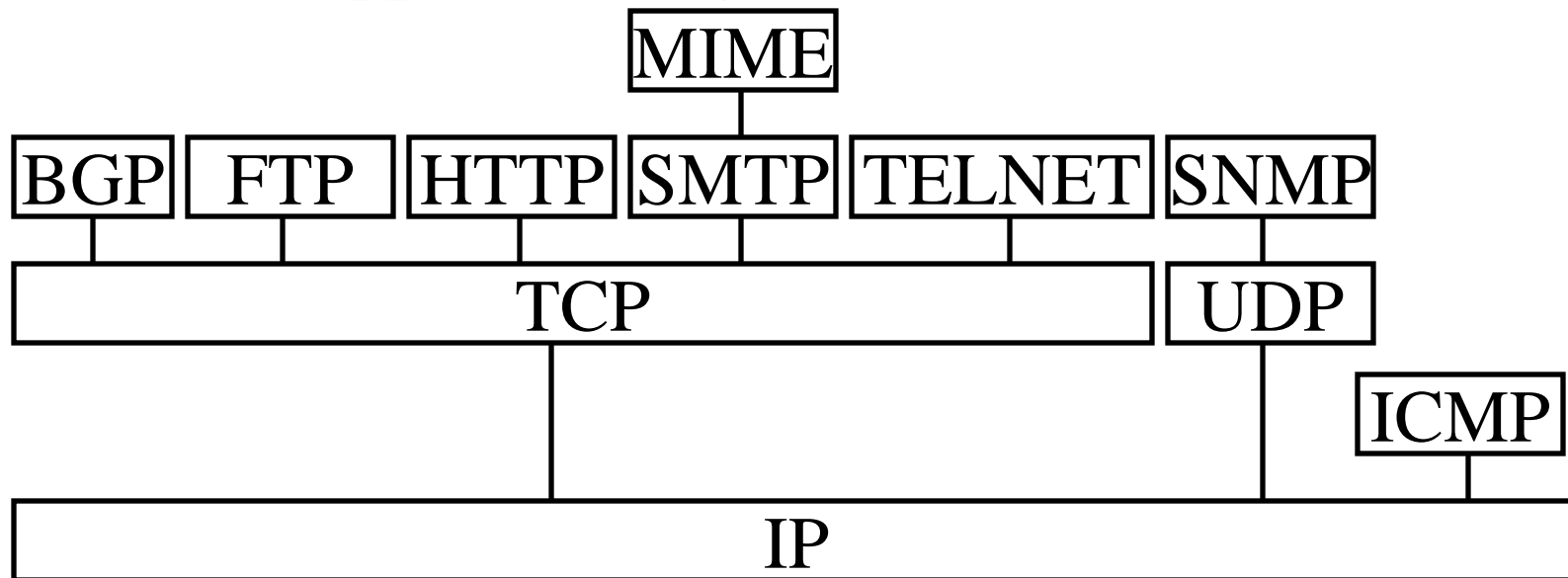
# Overview

❑ 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)

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                              ┌──────┐
                              │ MIME │
                              └──────┘
┌─────┬─────┬──────┬──────┬────────┬──────┐
│ BGP │ FTP │ HTTP │ SMTP │ TELNET │ SNMP │
└─────┴─────┴──────┴──────┴────────┴──────┘
┌────────────────────────────────┬──────┐
│              TCP               │ UDP  │
└────────────────────────────────┴──────┘
                                    ┌──────┐
                                    │ ICMP │
                                    └──────┘
┌───────────────────────────────────────┐
│                  IP                    │
└───────────────────────────────────────┘
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# Internetworking Terms

❑ End-system: Host

❑ Network: Provides data transfer between end-systems

❑ Internet: A collection of networks

❑ Subnetwork: Each component of an internet
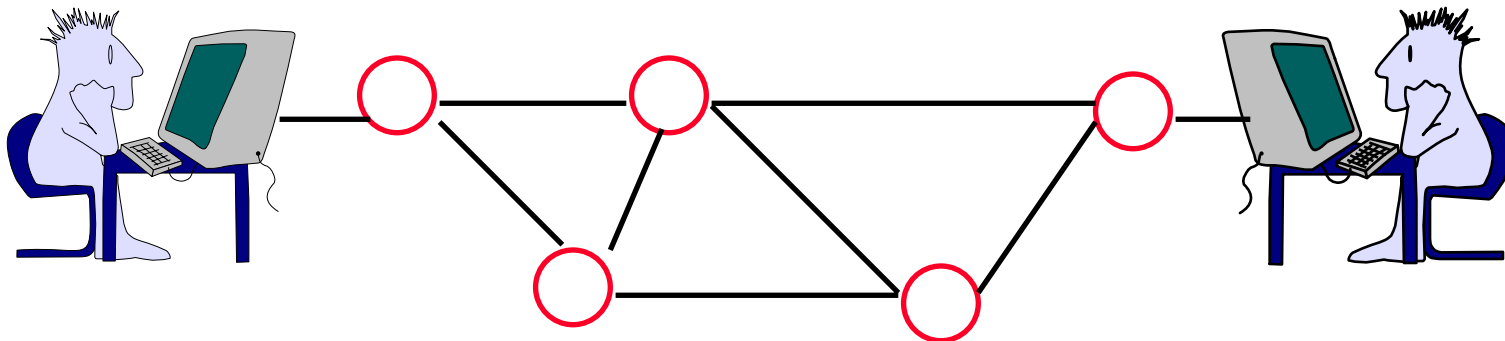
❑ Intermediate System: Connects two subnetworks

Host A — FTP | Telnet | SMTP — Subnet 1 — Intermediate System — Subnet 2 — FTP | Telnet | SMTP — Host B
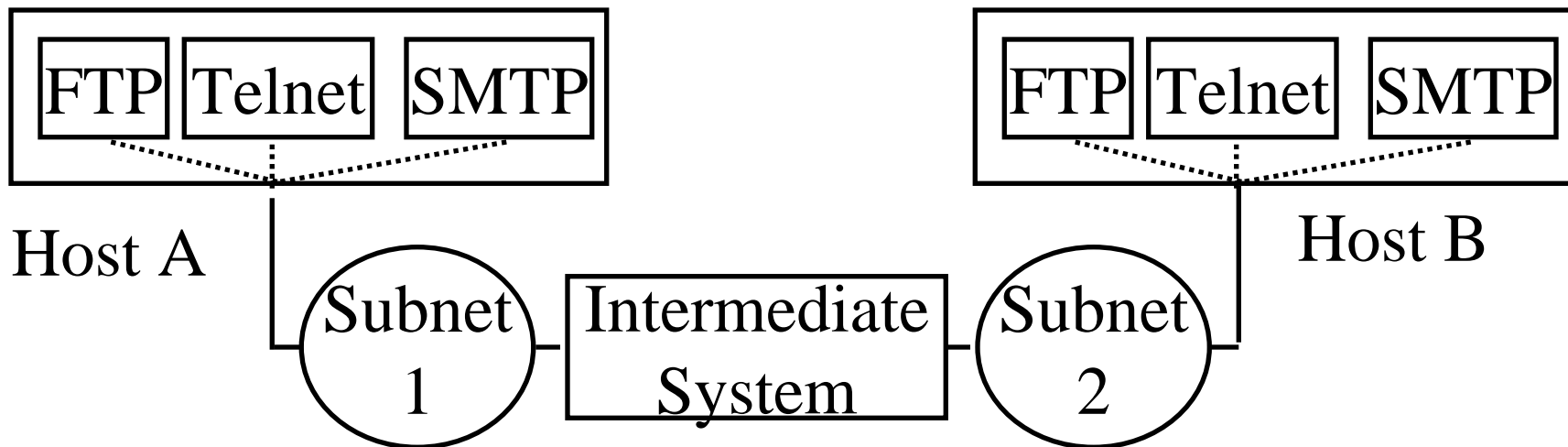
# Internet = Collection of Networks

- Any computer can talk to any other computer

Net 1    Net 2    Net 3    Net 4
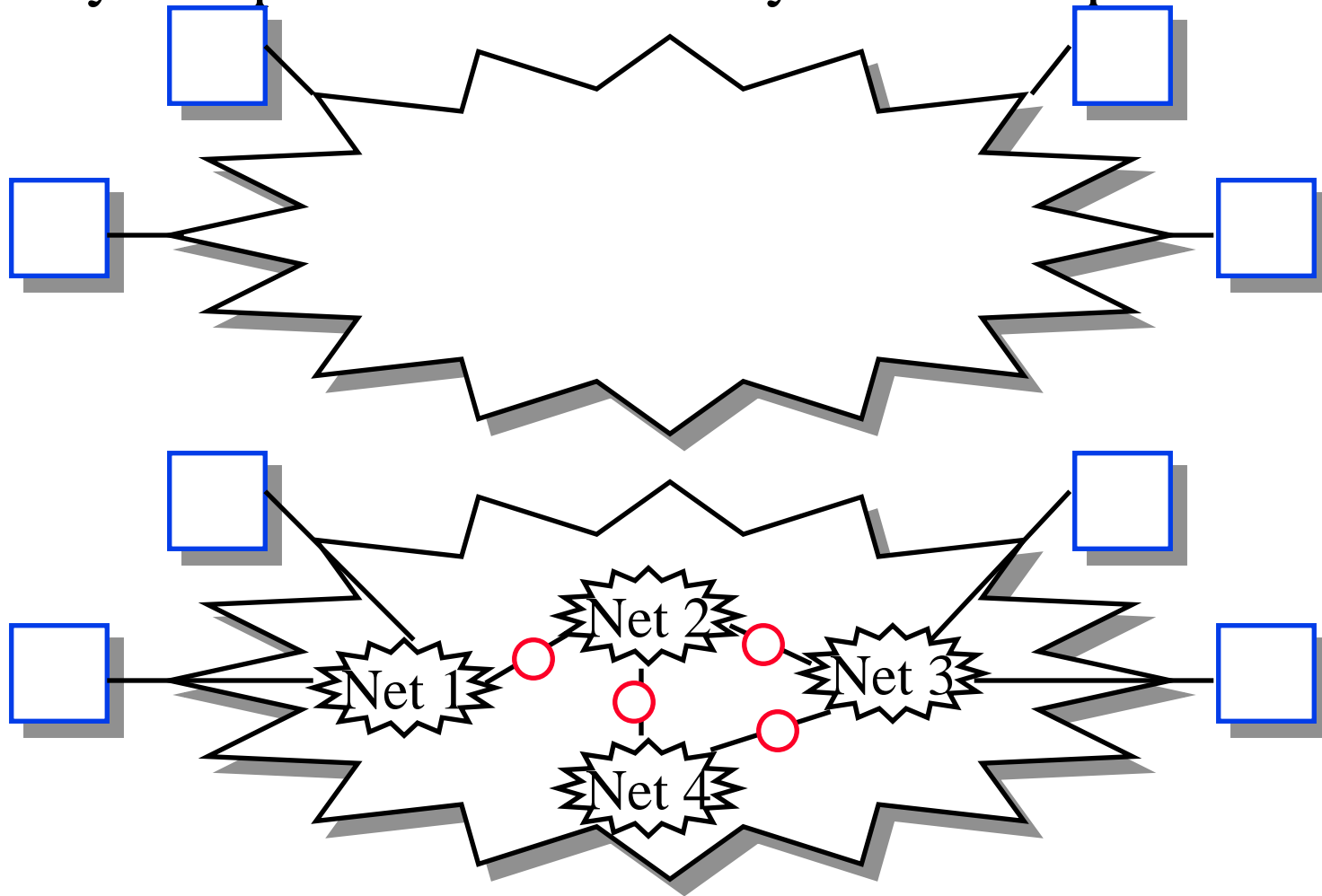
# Internet Protocol (IP)

❑ 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)

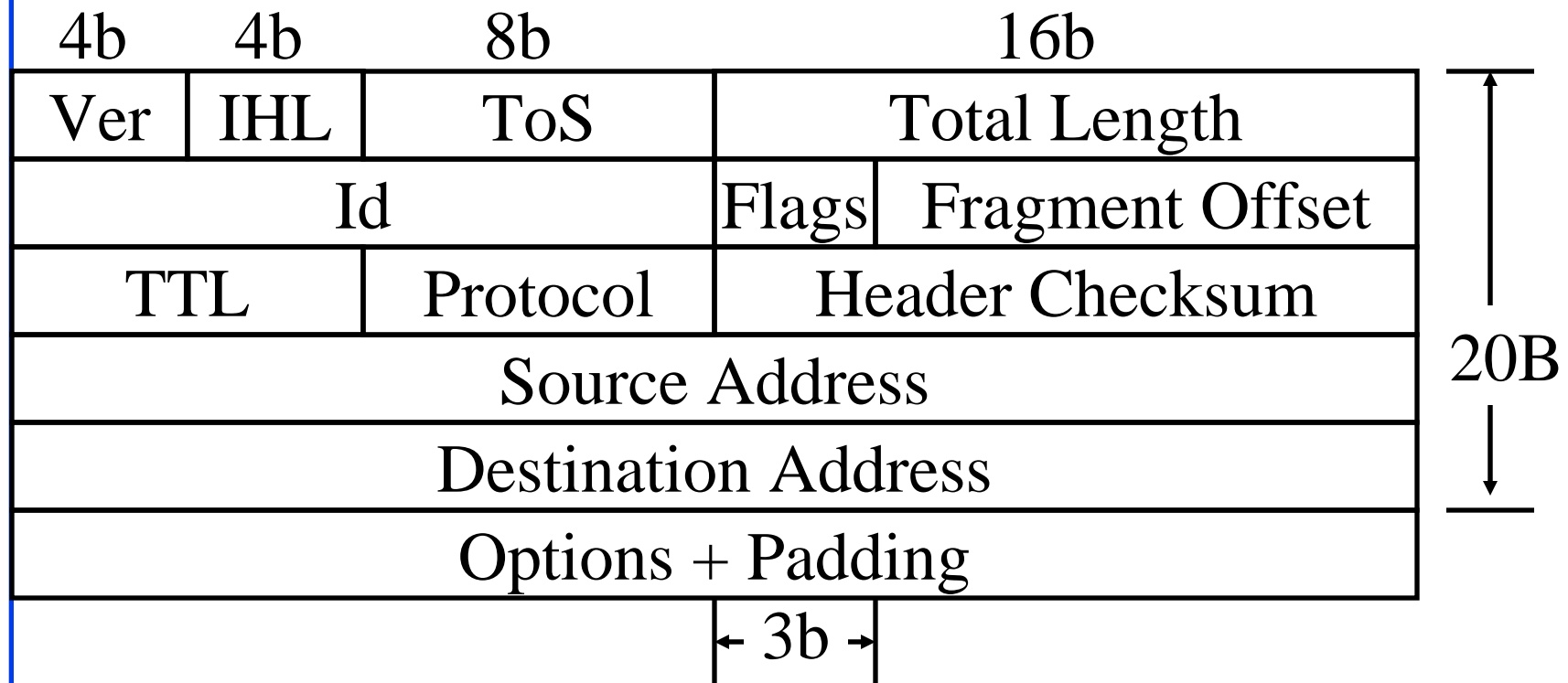❑ Connectionless service vs connection-oriented (circuits)

# IP Header

| 4b | 4b | 8b | 16b | |
|---|---|---|---|---|
| Ver | IHL | ToS | Total Length | |
| Id | | | Flags | Fragment Offset |
| TTL | | Protocol | Header Checksum | |
| Source Address | | | | |
| Destination Address | | | | |
| Options + Padding | | | | |

20B

← 3b →

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
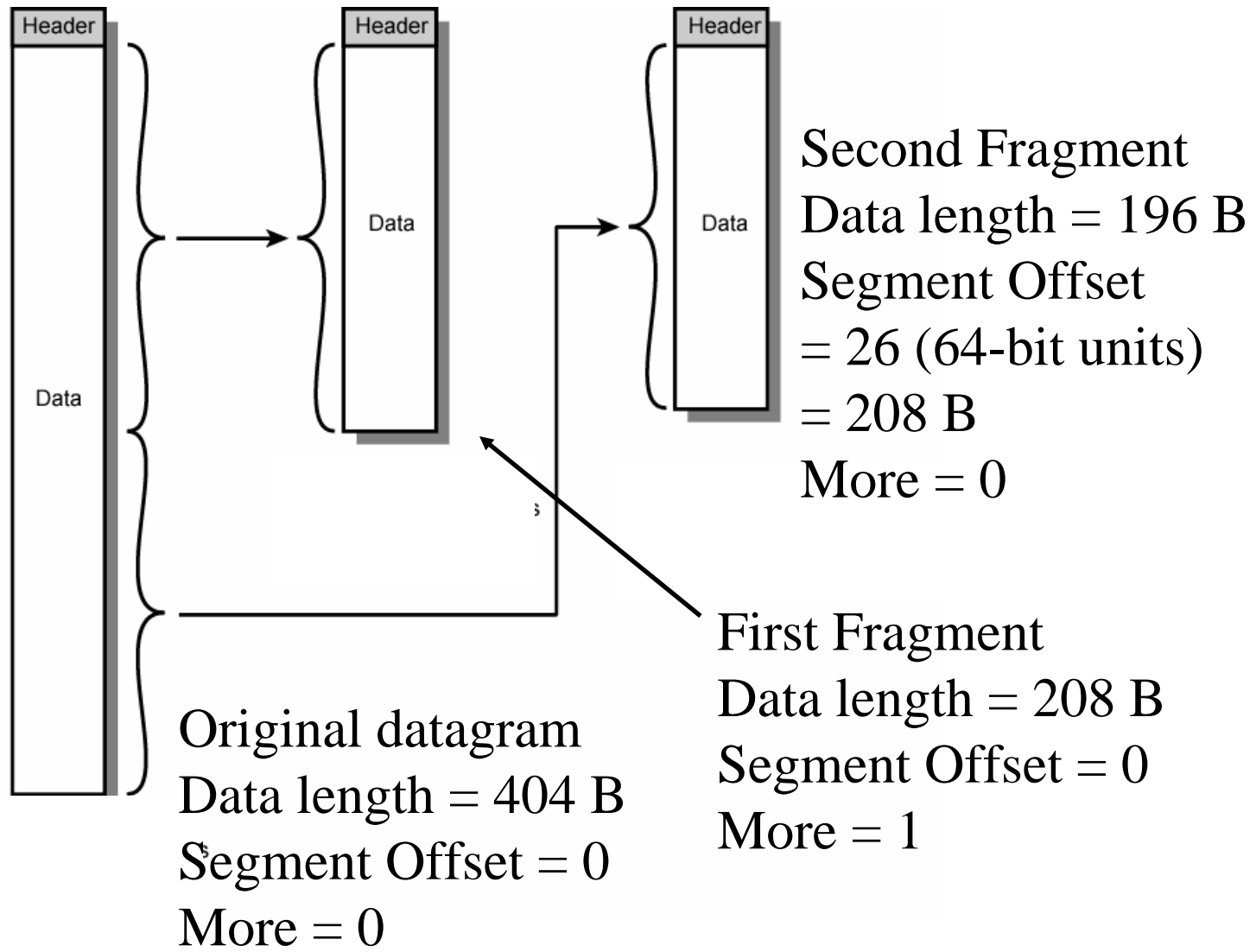
❑ Data (variable): Data + header $\leq$ 65,535 bytes

# 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
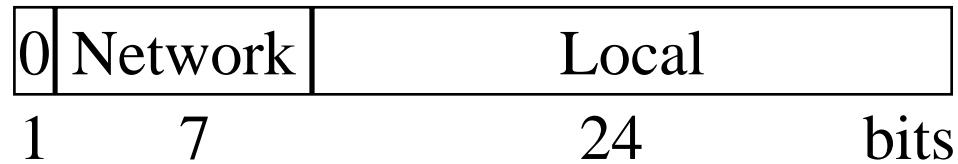
❏ Data Unit Identifier (ID)

   ❏ 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

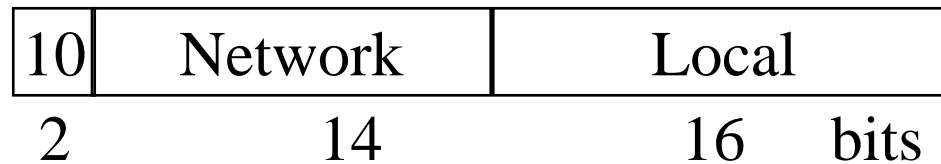      ▫ Indicates that this is not the last fragment

# Fragmentation Example
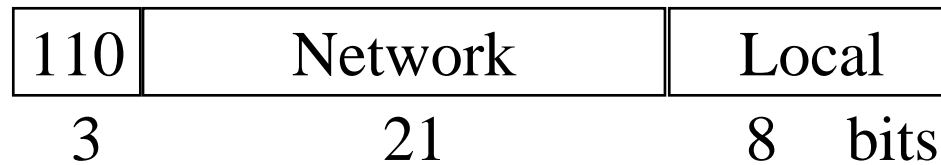


Second Fragment
Data length = 196 B
Segment Offset
= 26 (64-bit units)
= 208 B
More = 0

First Fragment
Data length = 208 B
Segment Offset = 0
More = 1

Original datagram
Data length = 404 B
Segment Offset = 0
More = 0

# IP Address

- Class A:

| 0 | Network | Local |
|---|---------|-------|
| 1 | 7 | 24    bits |

- Class B:

| 10 | Network | Local |
|----|---------|-------|
| 2 | 14 | 16    bits |

- Class C:

| 110 | Network | Local |
|-----|---------|-------|
| 3 | 21 | 8    bits |

- Class D:

| 1110 | Host Group (Multicast) |
|------|------------------------|
| 4 | 28    bits |

- Class E:

| 11110 | Future use |
|-------|-----------|
| 5 | 27      bits |
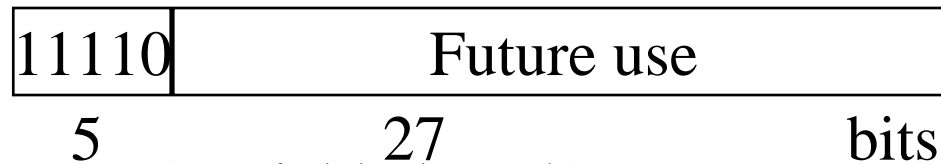
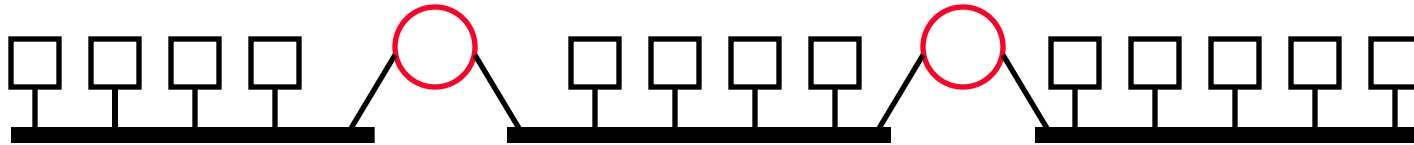- Local = Subnet + Host (Variable length)
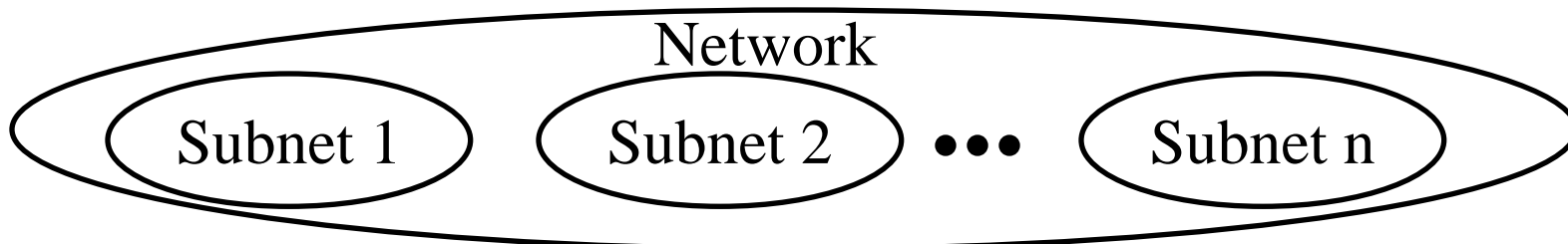
Router

Router

Subnet

# IP Addressing
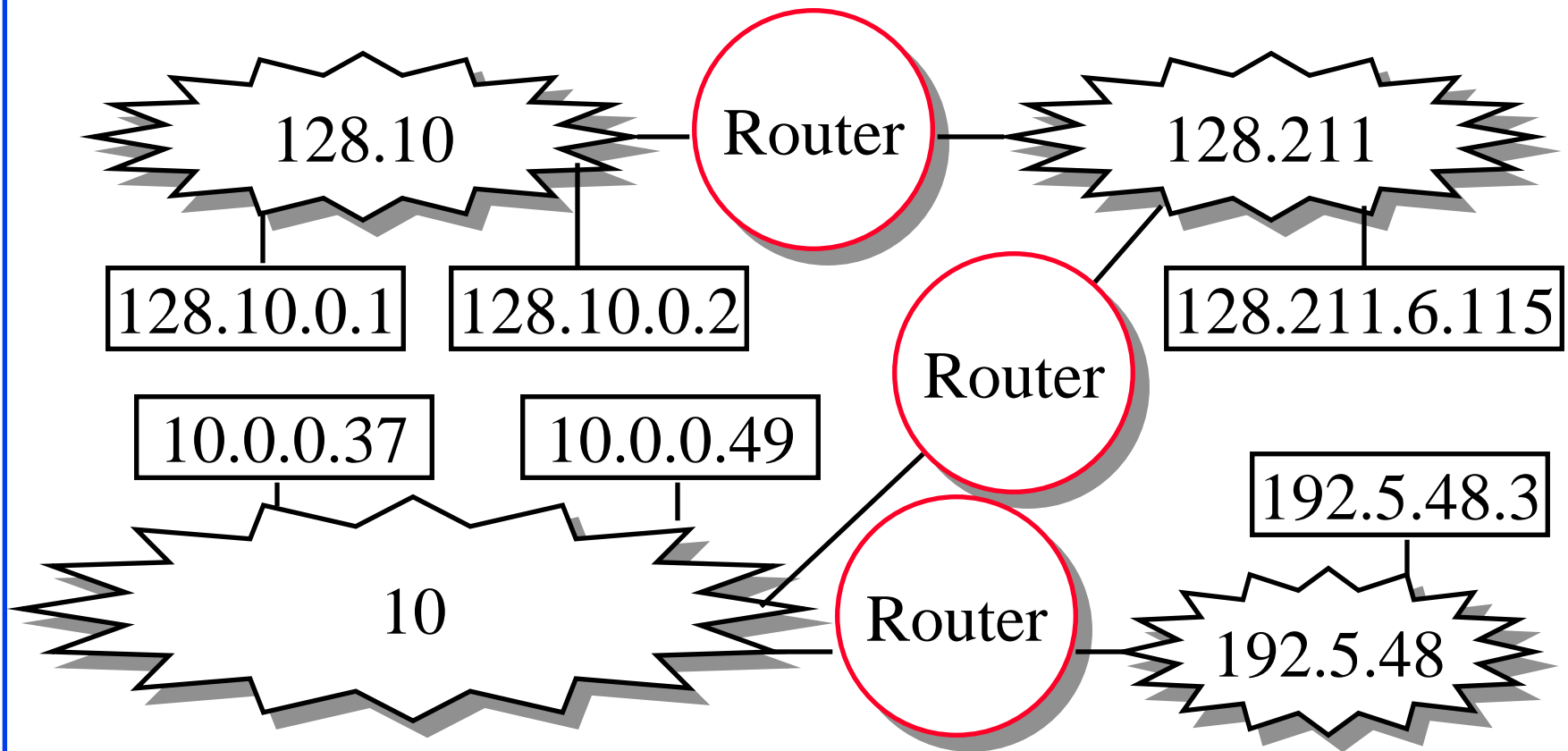


- All IP hosts have a 32-bit address. 128.10.0.1
  = 1000 0000  0000 1010  0000 0000  0000 0001

- 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 **datagram**s to destination network (subnet)

❑ Routers maintain a "routing table" of "next hops"
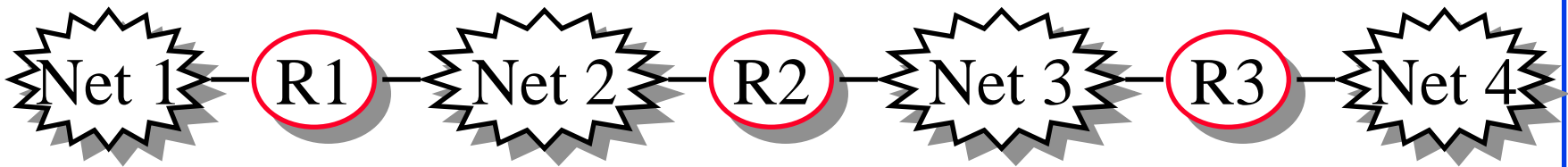
❑ Next Hop field does not appear in the datagram

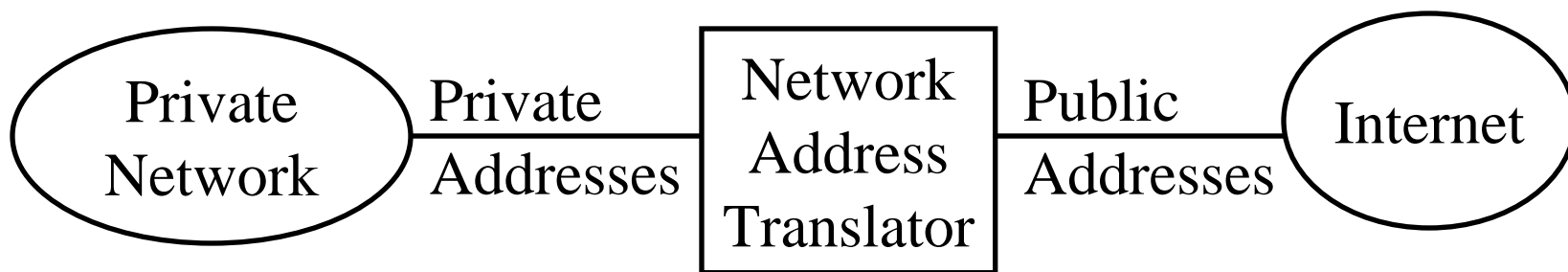Net 1 — R1 — Net 2 — R2 — Net 3 — R3 — Net 4

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)

Private Network — Private Addresses — Network Address Translator — Public Addresses — Internet

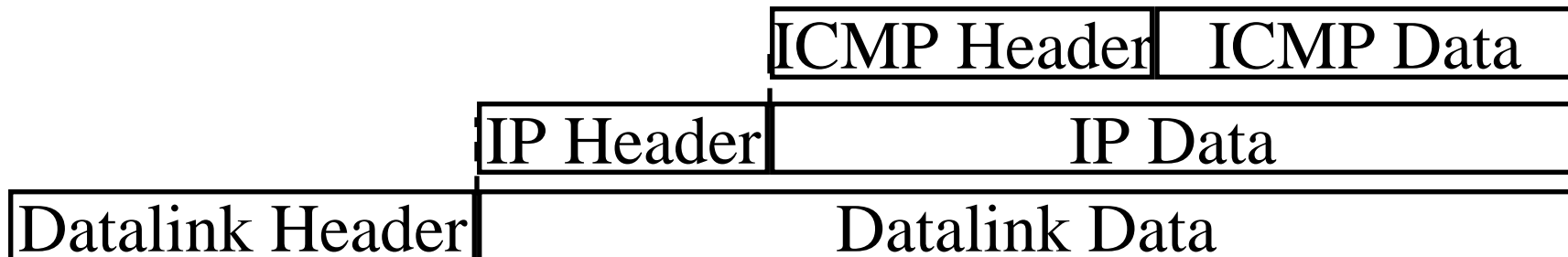# Address Resolution Protocol

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 ⌐╲─[R]      [E]
     |        |
```

❑ 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 Header | ICMP Data |
|---|---|

| IP Header | IP Data |
|---|---|

| Datalink Header | Datalink Data |
|---|---|

# 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
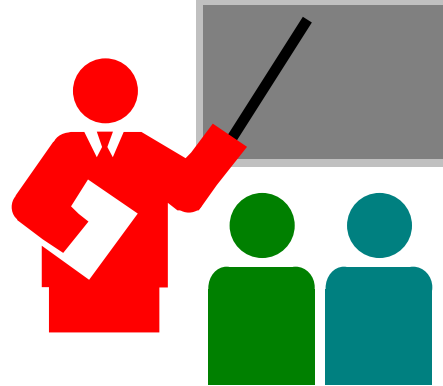
- Hosts, networks, subnetwork, Internet

- 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' 7th edition