

# Internet Protocol (IP)

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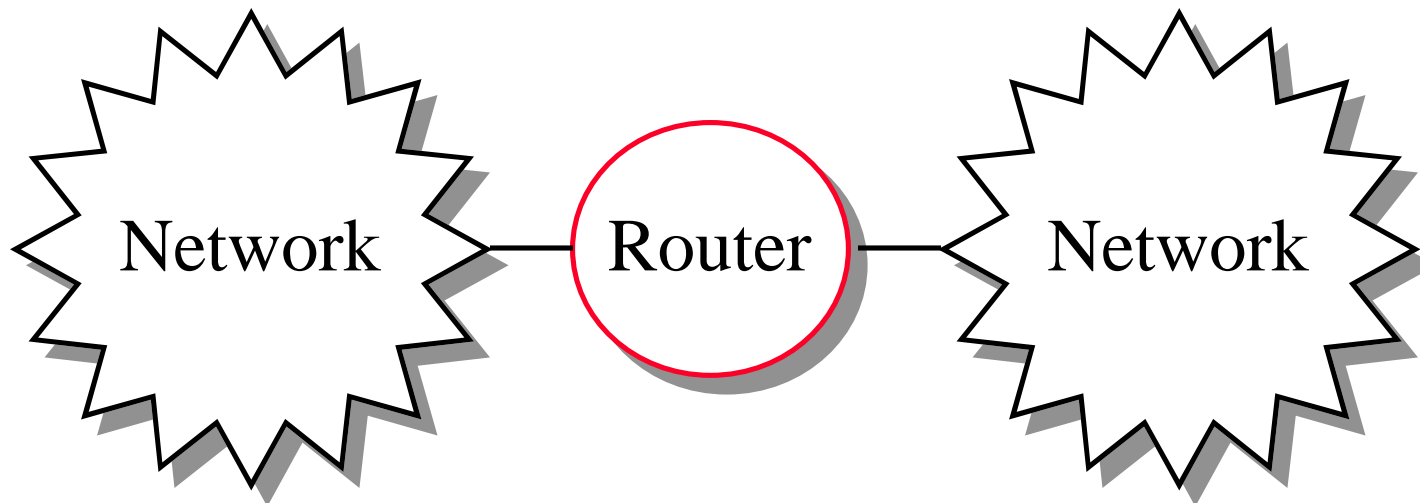


- ❑ Internetworking
- ❑ IP Address format
- ❑ IP data forwarding
- ❑ Fragmentation and reassembly

Ref: Chapters 13, 14, 16, and 17 of Comer's Computer Networks and Internets

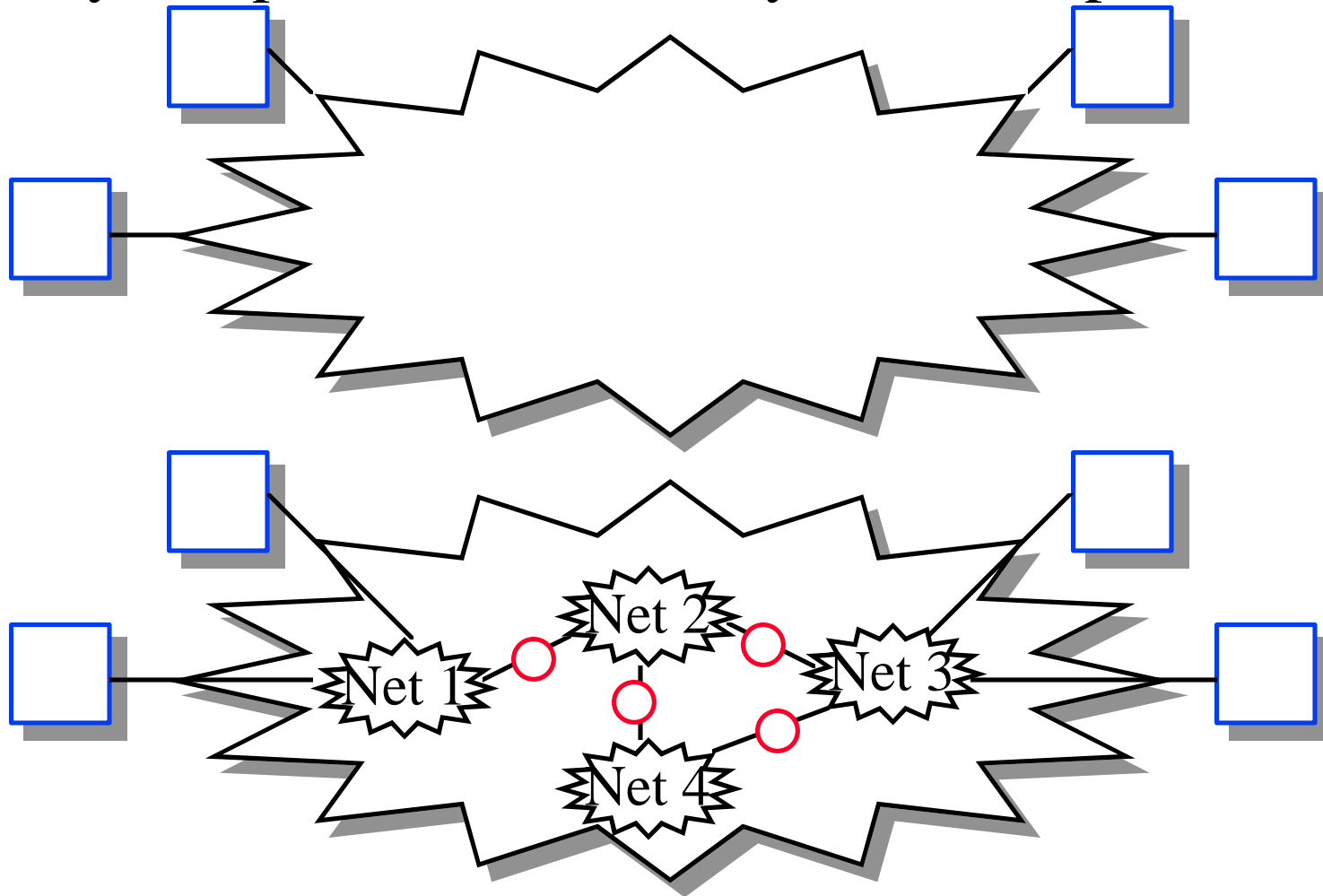
# Internetworking

- ❑ Internetwork = Collection of networks  
Connected via routers



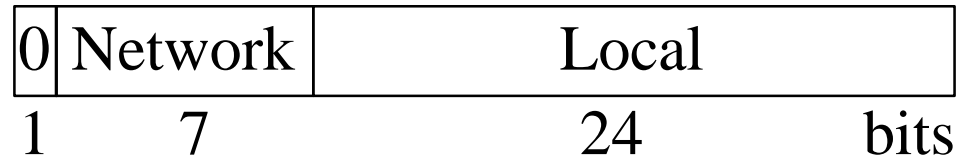
# Internet = Virtual Network

- Any computer can talk to any other computer

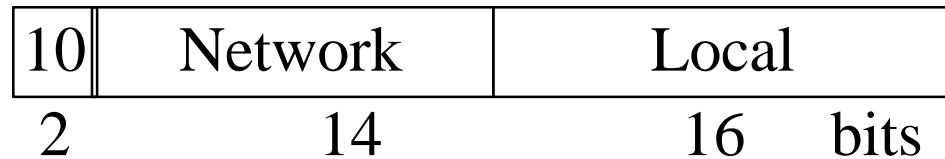


# IP Address

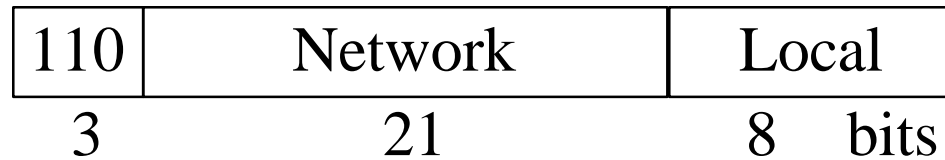
❑ Class A:



❑ Class B:



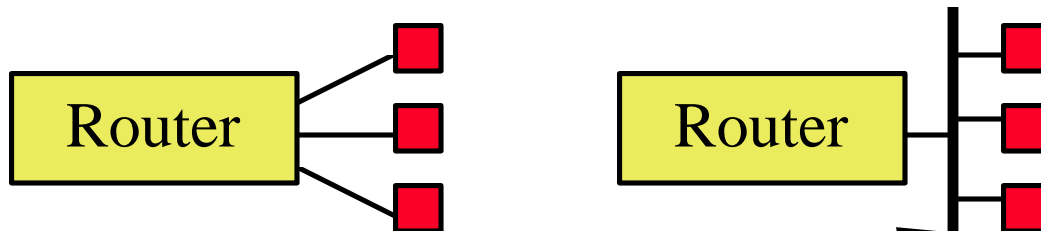
❑ Class C:



❑ Class D:



❑ Local = Subnet + Host (Variable length)



# Computing The Class of an Address

First 4 bits	Index	Class
0000	0	A
0001	1	A
0010	2	A
0011	3	A
0100	4	A
0101	5	A
0110	6	A
0111	7	A
1000	8	B
1001	9	B
1010	10	B
1011	11	B
1100	12	C
1101	13	C
1110	14	D
1111	15	E

# Classes and Dotted Decimal Notation

- Binary: 11000000 00000101 00110000 00000011  
Hex Colon: C0:05:30:03  
Dotted Decimal: 192.5.48.3

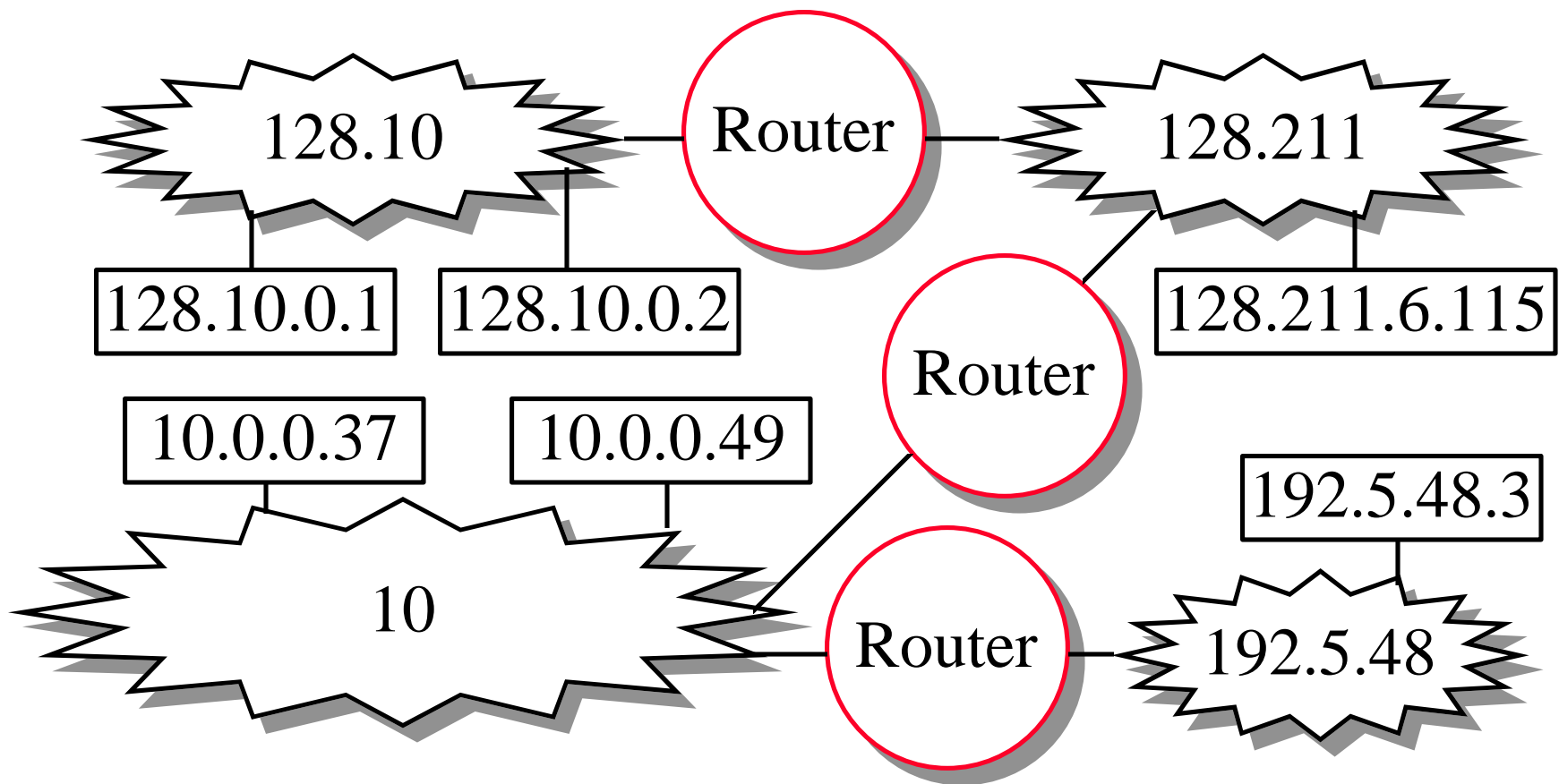
Class	Range
A	0 through 127
B	128 through 191
C	192 through 223
D	224 through 239
E	240 through 255

## Division of the Address Space

Class	Bits in Prefix	Max # of Nets	Bits in Suffix	Max # of Hosts per Net
A	7	128	24	16,777,216
B	14	16,384	16	65,536
C	21	2,097,152	8	256

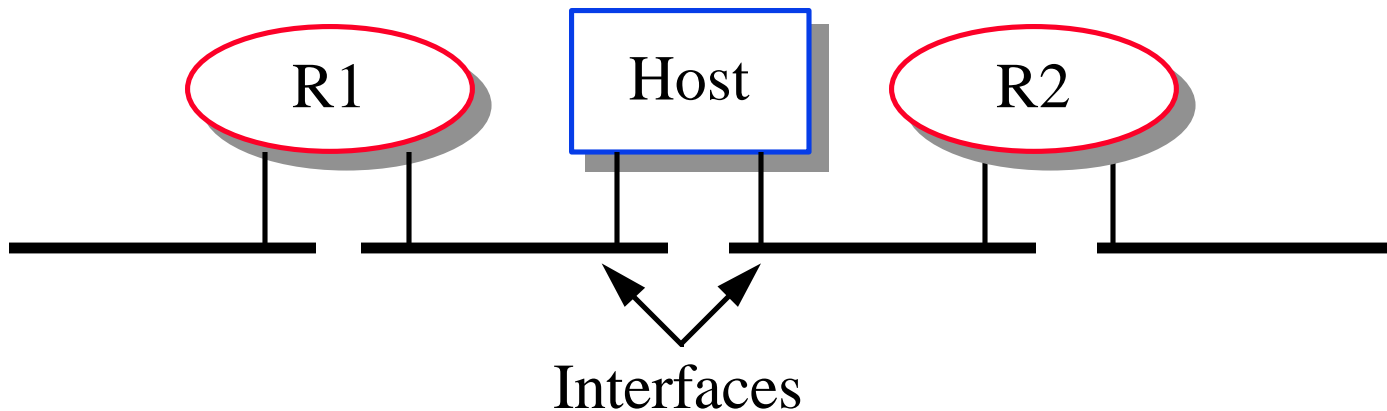
- ❑ Not all possible addresses can be used.

# An Addressing Example



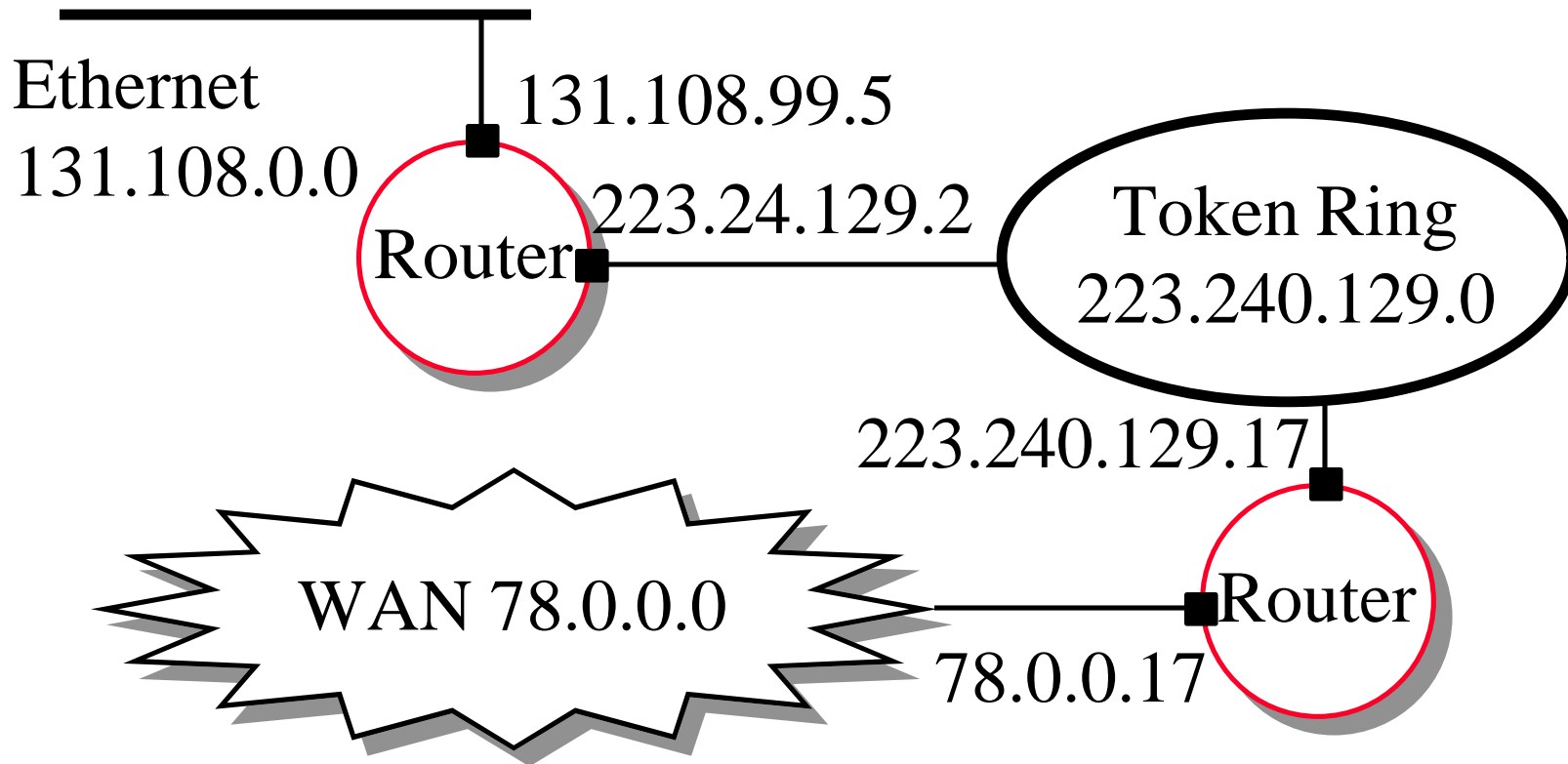
- All hosts on a network have the same network prefix

# Multi-Homed Hosts



- ❑ Each interface has an address.  
Two or more interfaces  $\Rightarrow$  Multi-homed hosts
- ❑ Multihoming is for reliability or performance

# Routers and the IP Addressing Principle



- ❑ Routers have two or more addresses.  
One for each interface.

# Special IP Addresses

- ❑ All-0 host suffix  $\Rightarrow$  Network Address
- ❑ All-0s  $\Rightarrow$  This computer
- ❑ All-1 host suffix  $\Rightarrow$  All hosts on the destination net (directed broadcast),  
All-0 host suffix  $\Rightarrow$  Berkeley directed broadcast address
- ❑ All-1s  $\Rightarrow$  All hosts on this net (limited broadcast)
- ❑ 127.\*.\*  $\Rightarrow$  Looback through IP layer

# Homework

- ❑ Read chapters 13, 14
- ❑ Submit answer to exercise 14.8  
(requires 14.6 and 14.7 also)
- ❑ Use your program to printout characteristics of the following addresses using a subnet mask of 255.255.255.0: 164.107.61.200, 164.107.61.0, 164.107.61.255, 127.107.61.200, 0.0.0.0

# IP Features

- ❑ Connectionless service
- ❑ Variable size datagrams
- ❑ Best-effort delivery: Delay, out-of-order, corruption, and loss possible. Higher layers should handle these.
- ❑ Handles only data forwarding  
Uses routing tables prepared by other protocols, e.g.,  
Open Shortest Path First (OSPF),  
Routing Information Protocol (RIP)
- ❑ Provides only “Send” and “Delivery” services  
Error and control messages generated by  
Internet Control Message Protocol (ICMP)

# 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

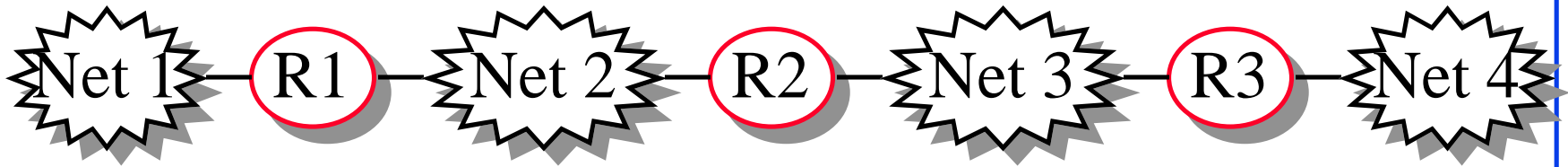


Table at R2:

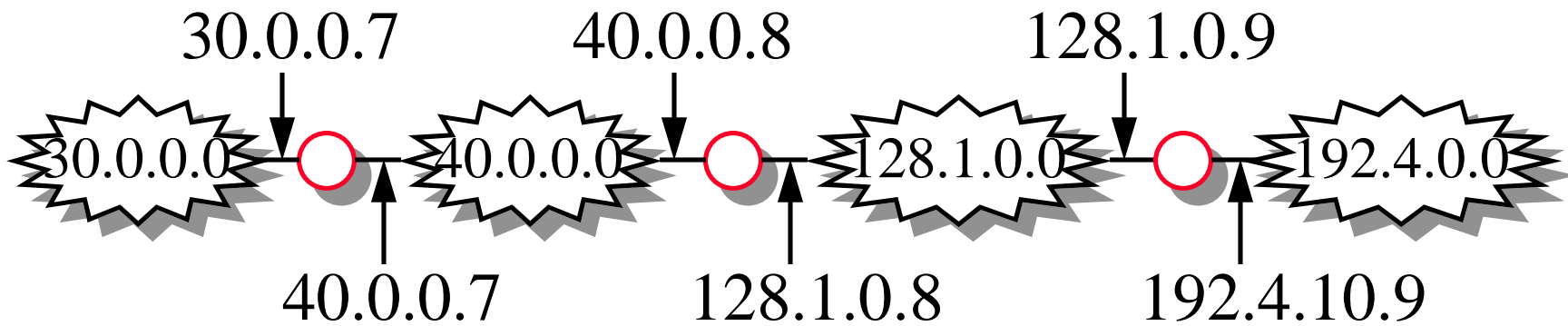
Destination      Next Hop

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

Fig 16.2

# IP Addresses and Routing Table Entries

- IF ((Mask[i] & Destination Addr) == Destination[i])  
*Forward to NextHop[i]*



Destination	Mask	Next Hop
30.0.0.0	255.0.0.0	40.0.0.7
40.0.0.0	255.0.0.0	Deliver direct
128.1.0.0	255.255.0.0	Deliver direct
192.4.10.0	255.255.255.0	128.1.0.9

# IP Datagram Format

Vers	H. Len	Service Type	Total Length	
Identification			Flags	Fragment Offset
Time to live	Type		Header Checksum	
Source IP Address				
Destination IP Address				
IP Options (May be omitted)				Padding
Data				

# IP Format

- ❑ 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  
Total must be less than 64 kB.
- ❑ Identifier (16 bits): Helps uniquely identify the datagram during its life for a given source, destination address

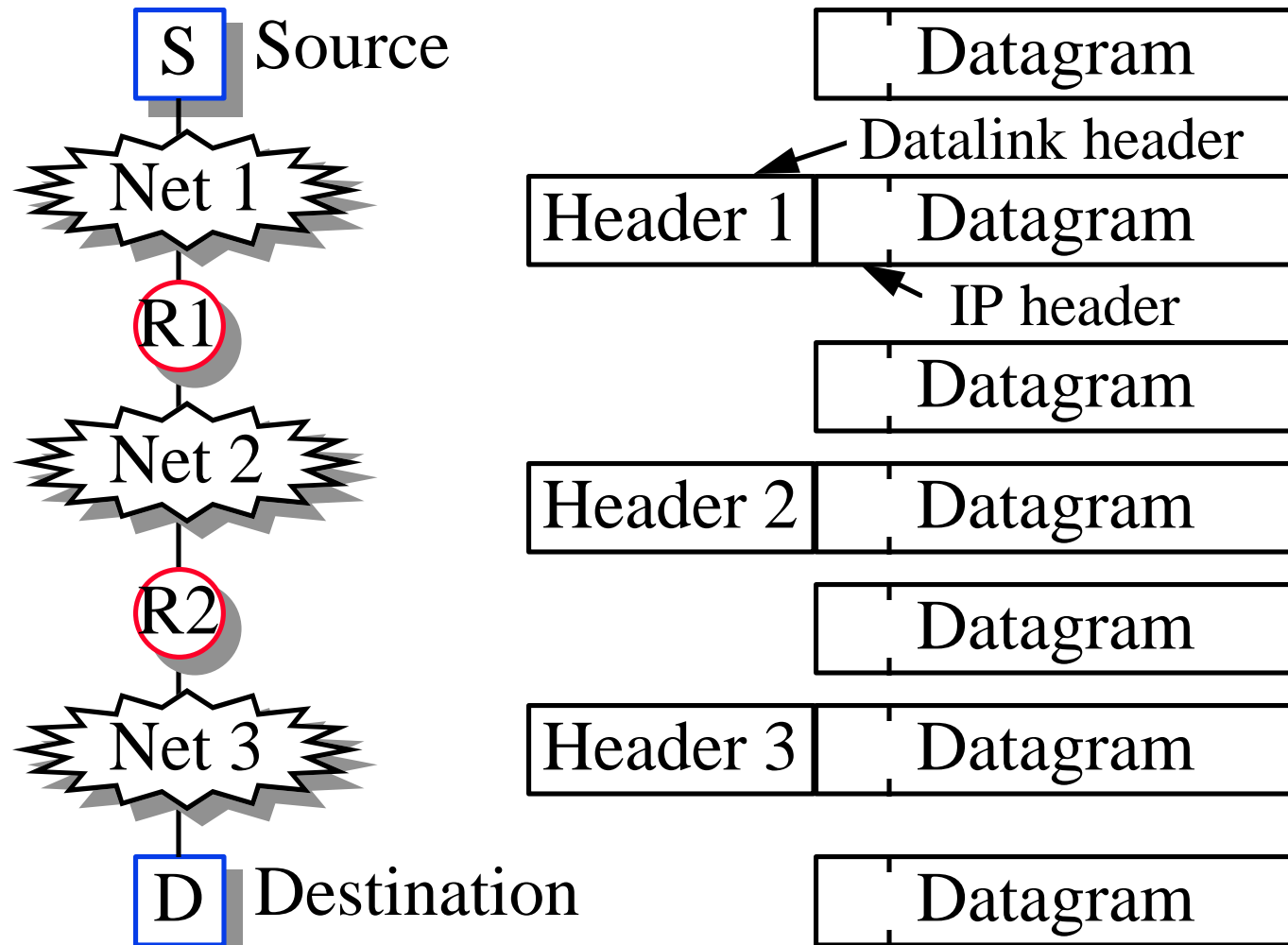
## IP Header (Cont)

- ❑ 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): Original source.  
Does not change along the path.
- ❑ Destination Address (32 bits): Final destination.  
Does not change along the path.
- ❑ 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

# Transmission Across An Internet



- Datalink header changes at every hop

# Maximum Transmission Unit

- ❑ Each subnet has a maximum frame size  
Ethernet: 1518 bytes  
FDDI: 4500 bytes  
Token Ring: 2 to 4 kB
- ❑ Transmission Unit = IP datagram (data + header)
- ❑ Each subnet has a maximum IP datagram length: MTU

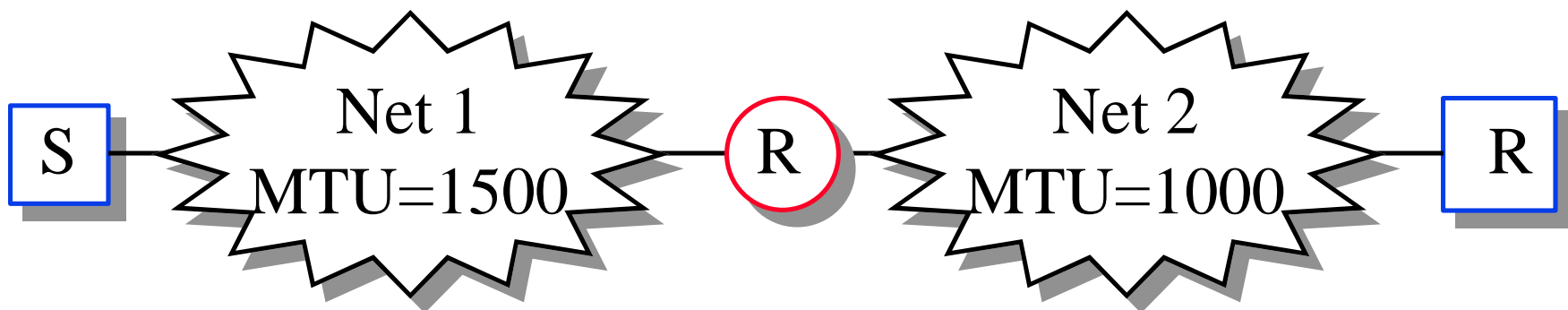


Fig 17.3

# IP Protocol Numbers

Decimal	Key word	Protocol
0		Reserved
1	ICMP	Internet Control Message Protocol
2	IGMP	Internet Group Management Protocol
4	ST	Stream Protocol
5	TCP	Transmission Control Protocol
8	EGP	Exterior Gateway Protocol
9	IGP	Interior Gateway Protocol
17	UDP	User Datagram Protocol

# IP Options Coding

Type	Length	Value
1B	1B	$n$ B

Flag Copy	Class	Number
1b	2b	5b

- ❑ Flag Copy: 0 = Copy the option only into the first fragment of a fragmented datagram  
1 = Copy into all fragments
- ❑ Class: 0=User or control, 1=Reserved, 2=Diagnostics, 3=reserved

# IP Options

Class	Number	Length	Description
0	0	0	End of Options
0	1	0	No Op
0	2	11	Security
0	3	Var	Loose Source Routing
0	7	Var	Record Route
0	8	4	Stream ID (obsolete)
0	9	Var	Strict Source Routing
2	4	Var	Internet Time-Stamp

# IP Source Routing

Code	Length	Pointer	Router Data
------	--------	---------	-------------


P	128.2.3.4	128.7.8.9	128.10.4.12
---	-----------	-----------	-------------

P	128.2.3.4	128.7.8.9	128.10.4.12
---	-----------	-----------	-------------

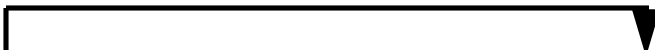
# Route Recording

Code	Length	Pointer	Route Data
------	--------	---------	------------

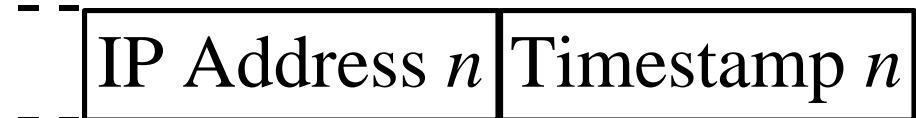
P	128.2.3.4	Empty	Empty
---	-----------	-------	-------



P	128.2.3.4	128.7.8.9	Empty
---	-----------	-----------	-------

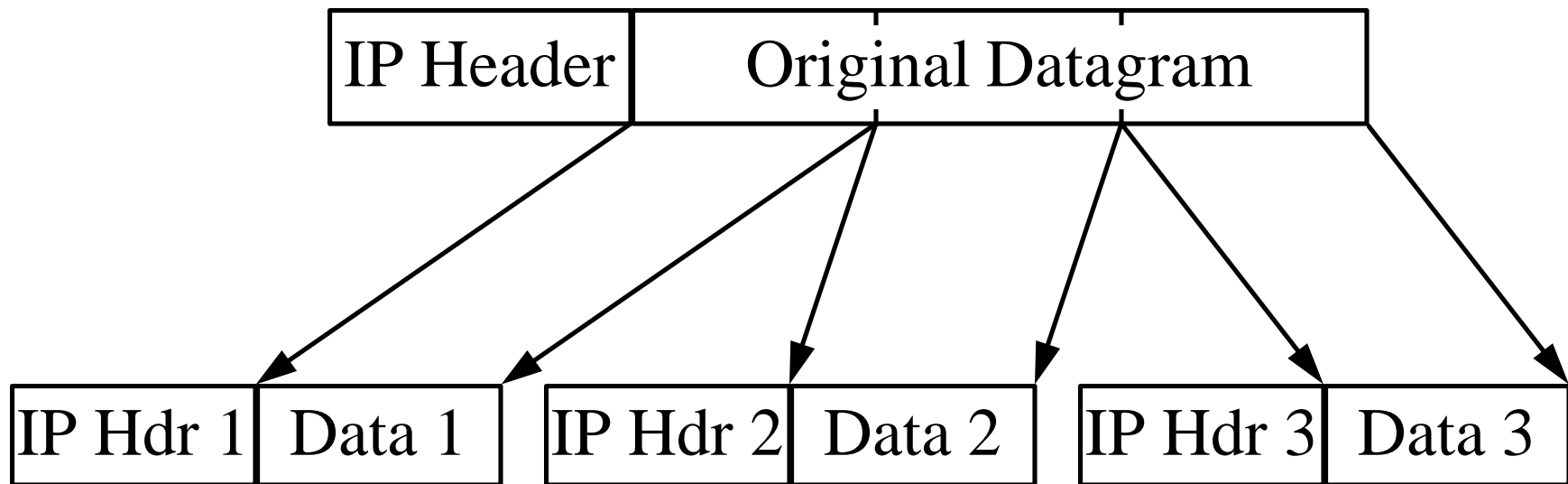


# Timestamp Option

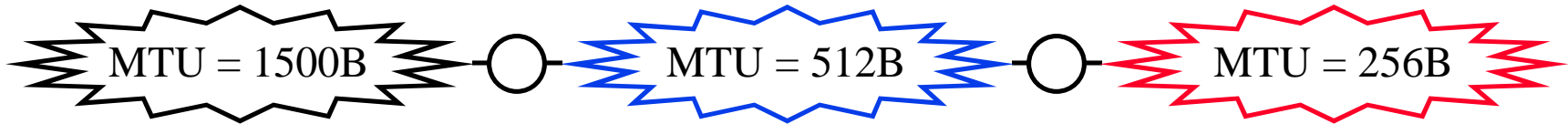


# Fragmentation

- ❑ Datagrams larger than MTU are fragmented
- ❑ Original header is copied to each fragment and then modified (fragment flag, fragment offset, length,...)



# Fragmentation



ID = 12345, More = 1  
Offset = 160W, Len = 1500B

ID = 12345, More = 1  
Offset = 0W, Len = 512B

ID = 12345, More = 1  
Offset = 0W, Len = 256B

ID = 12345, More = 1  
Offset = 32W, Len = 256B

ID = 12345, More = 1  
Offset = 64W, Len = 512B

ID = 12345, More = 1  
Offset = 64W, Len = 256B

ID = 12345, More = 1  
Offset = 96W, Len = 256B

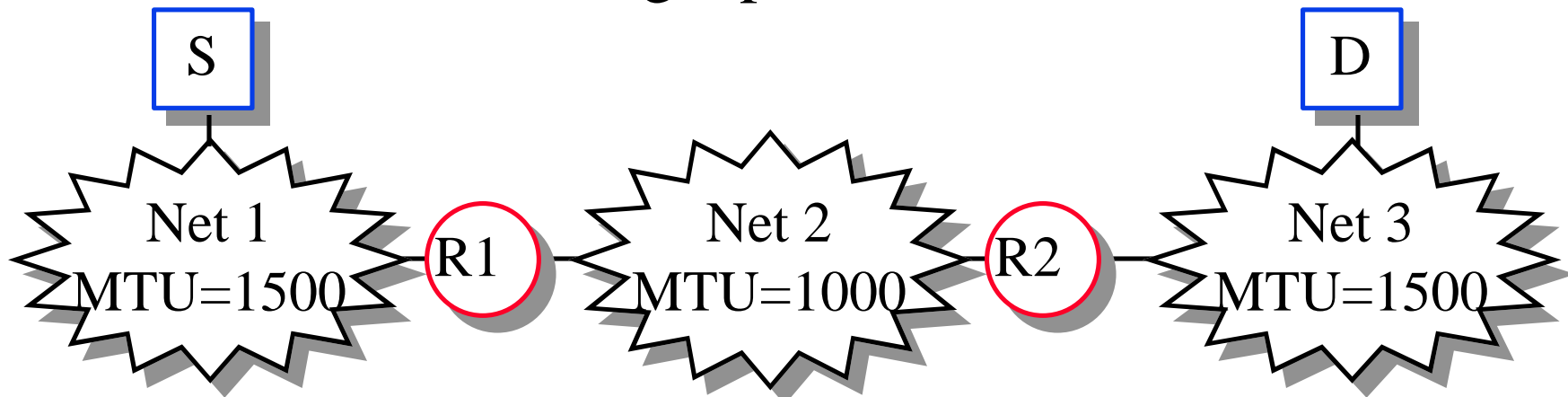
ID = 12345, More = 1  
Offset = 128W, Len = 476B

ID = 12345, More = 1  
Offset = 128W, Len = 256B

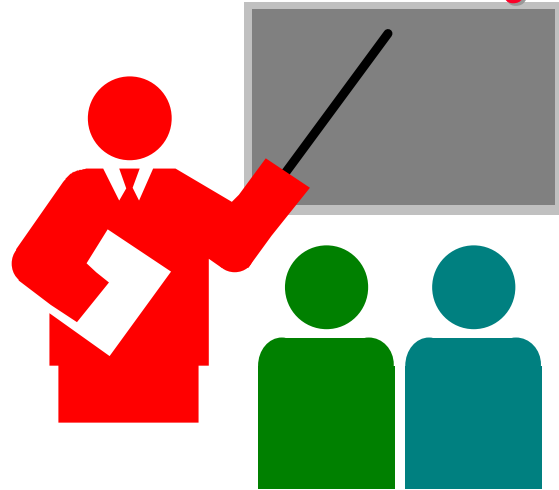
ID = 12345, More = 1  
Offset = 160W, Len = 220B

# Reassembly

- ❑ Reassembly only at the final destination
- ❑ Partial datagrams are discarded after a timeout
- ❑ Fragments can be further fragmented along the path. Subfragments have a format similar to fragments. It is not possible to tell how many times fragmented.
- ❑ Minimum MTU along a path  $\Rightarrow$  Path MTU



# Summary



- ❑ IPv4 uses 32-bit addresses organized as network prefix and host suffix.
- ❑ Four classes of networks: A, B, C, D
- ❑ Routers determine next hop using routing tables
- ❑ IP provides connectionless unreliable service

# Homework

- ❑ Read Chapters 16, 17
- ❑ Submit answers to exercises 16.7, 17.4