IP Network Protocol

CE 352, Computer Networks

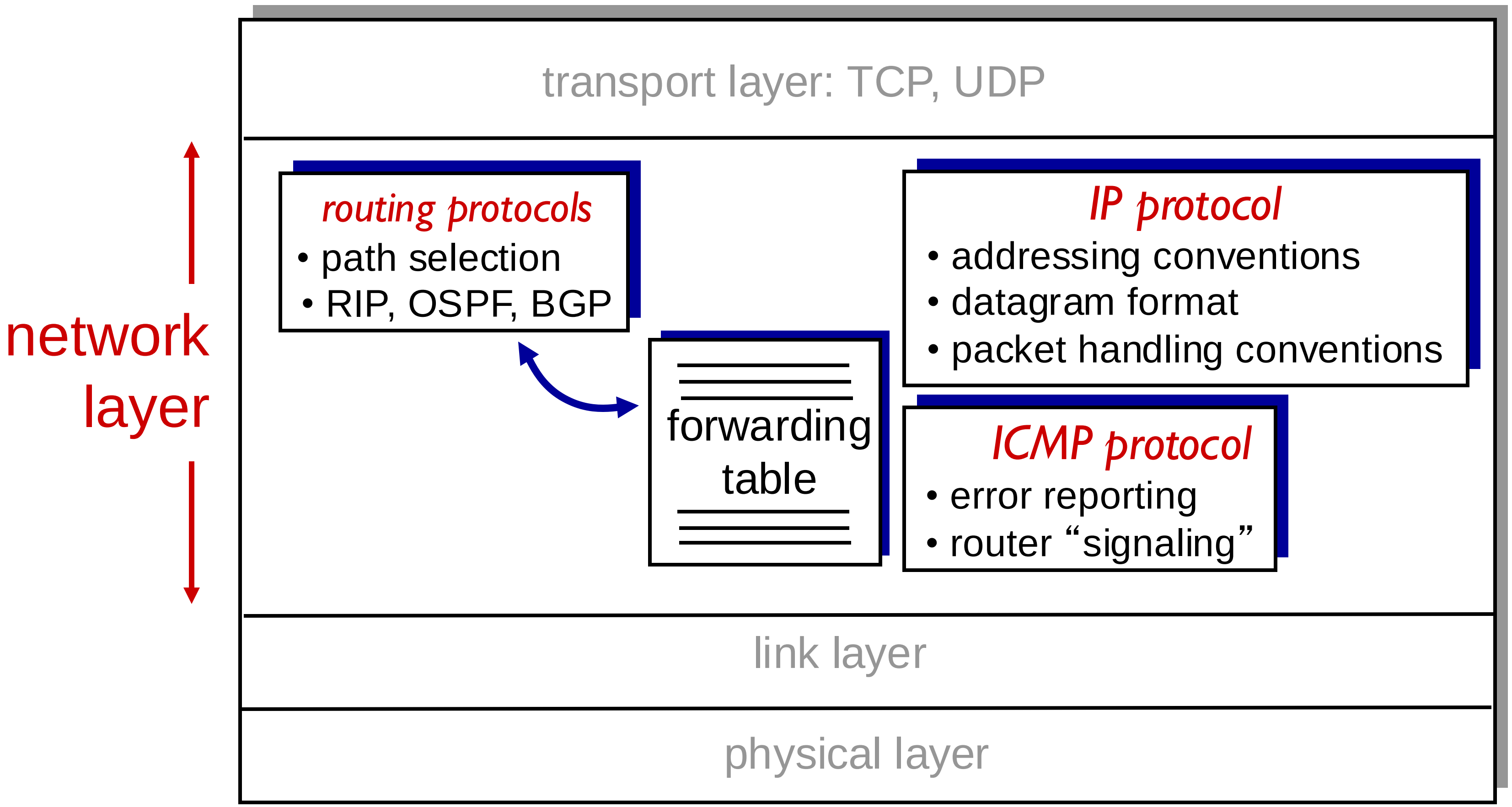
Salem Al-Agtash

Lecture 13

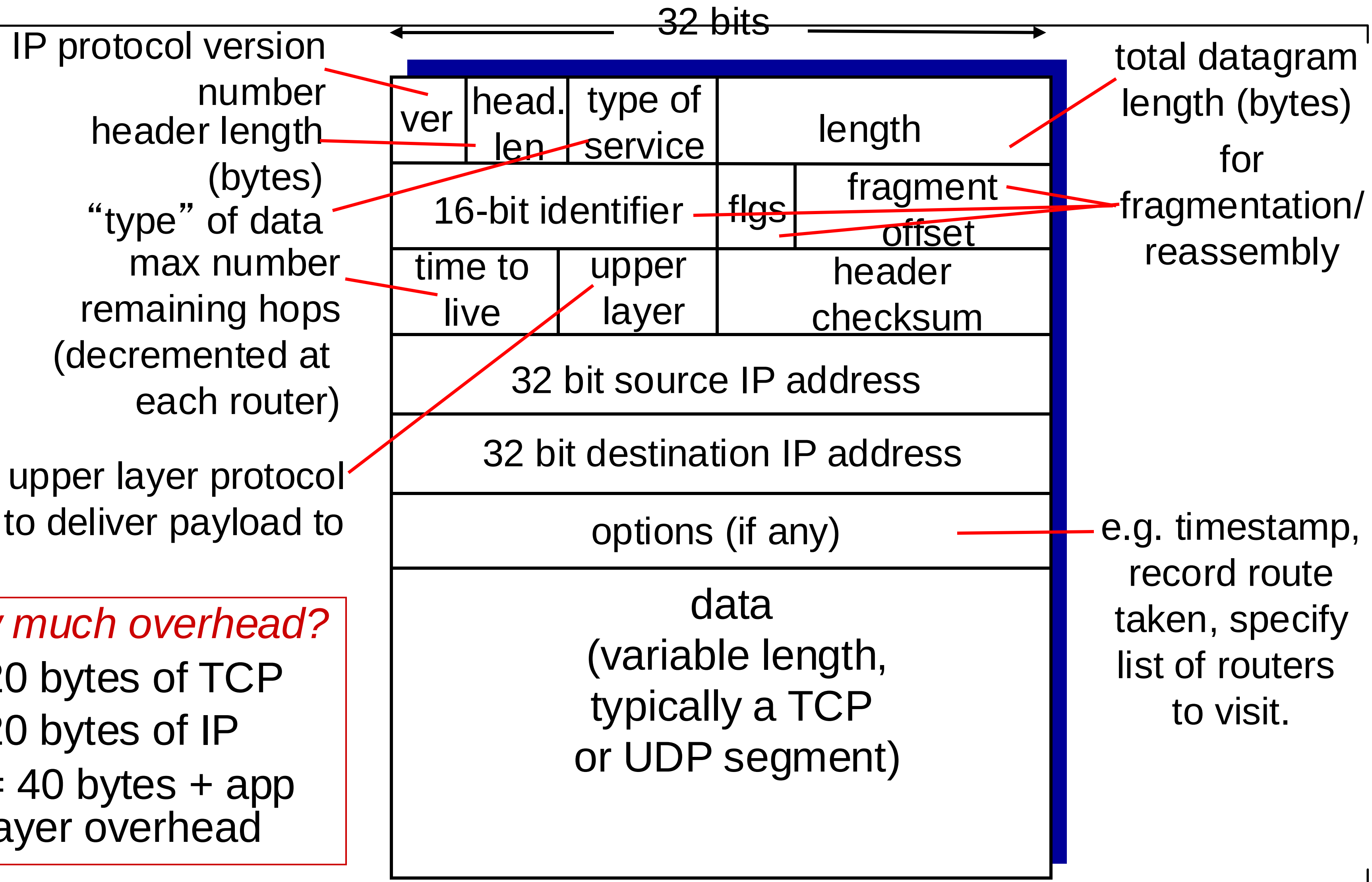
Slides are adapted from Computer Networking: A Top Down Approach, 7th Edition © J.F Kurose and K.W. Ross

The Internet network layer

host, router network layer functions:



IP datagram format

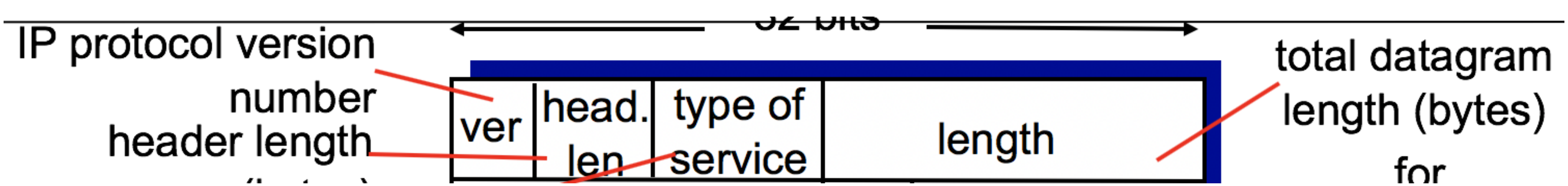


how much overhead?

- 20 bytes of TCP
- 20 bytes of IP
- = 40 bytes + app layer overhead

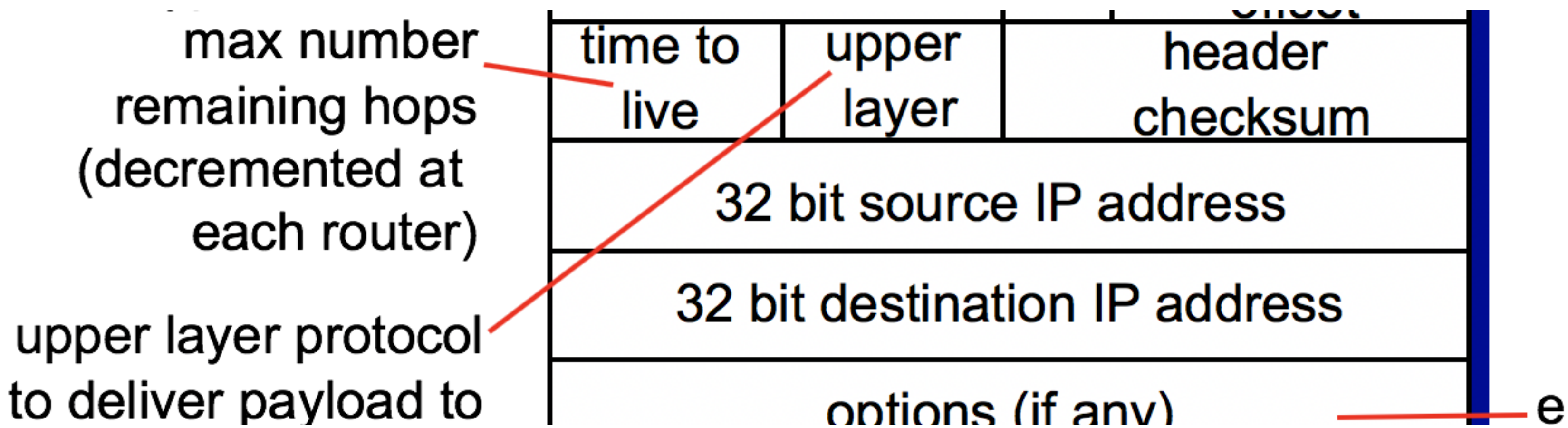
Header details

- Reading packet
  - IP protocol version number: IPv4 (4), IPv6 (6)
  - Header length: 5 for a 20-byte IPv4 header
  - Total datagram length (16 bits): bytes in the packet, maximum size is $(2^{16} - 1)$ bytes
- 8-bit Type of Service", or "Differentiated Services Code Point (DSCP)" (8 bits)
  - Allow packets to be treated differently based on needs: low delay for audio, high bandwidth for bulk transfer



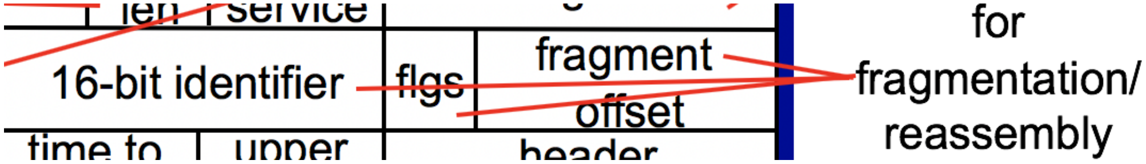
Header details

- 32-bit IP source and destination addresses to reach destination and come back
- Upper layer 8-bit: TCP (6), UDP (17)
- 16-bit Checksum: router discards packets that are not correct
- 8-bit Time-to-Live (TTL): decremented at each hop, packet discarded if reaches 0 (time exceeded to reach)



Header details

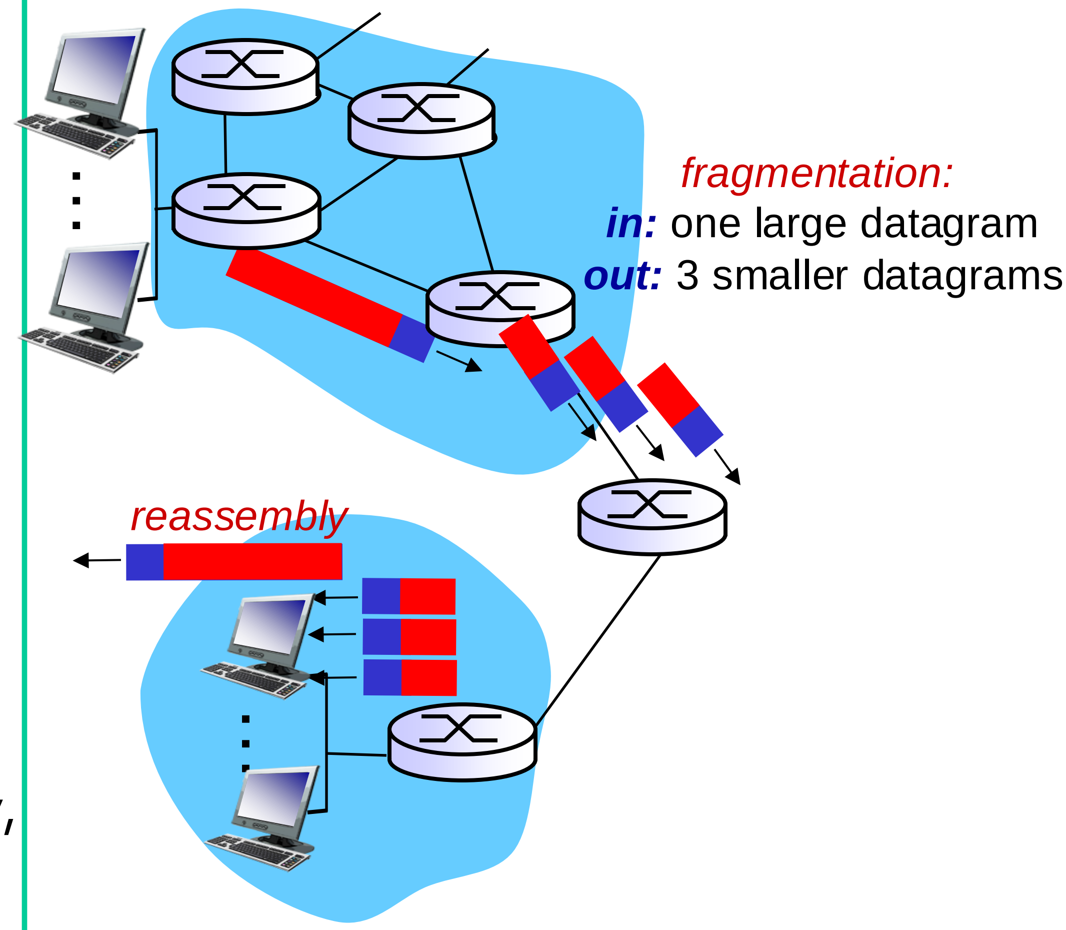
- Fragmentation/ reassembly:
  - Router splits packets into multiple pieces (“fragments”) if the packet exceeds Max Transmission Unit for next hop link
  - 32-bit fragmentation information:
    - Packet identifier
    - Flags (0 for last fragment)
    - fragment offset



IP fragmentation, reassembly

- Network links have MTU (max transfer size) - largest possible link-level frame*
  - different link types, different MTUs
- large IP datagram divided ("fragmented") within net
  - one datagram becomes several datagrams
  - "reassembled" only at final destination
  - IP header bits used to identify, order related fragments

*MSS (max.segment.size) in transport layer



IP fragmentation, reassembly

example:

- 4000 byte datagram
- MTU = 1500 bytes

	length	ID	fragflag	offset	
	=4000	=x	=0	=0	

one large datagram becomes several smaller datagrams

1480 bytes in data field

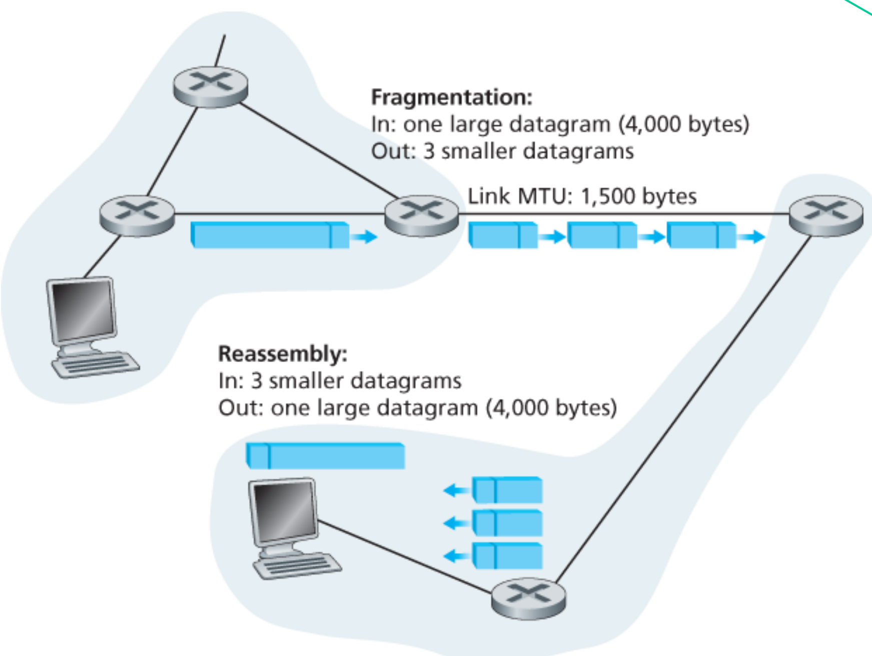
1480/8

	length	ID	fragflag	offset	
	=1500	=x	=1	=0	

	length	ID	fragflag	offset	
	=1500	=x	=1	=185	

	length	ID	fragflag	offset	
	=1040	=x	=0	=370	

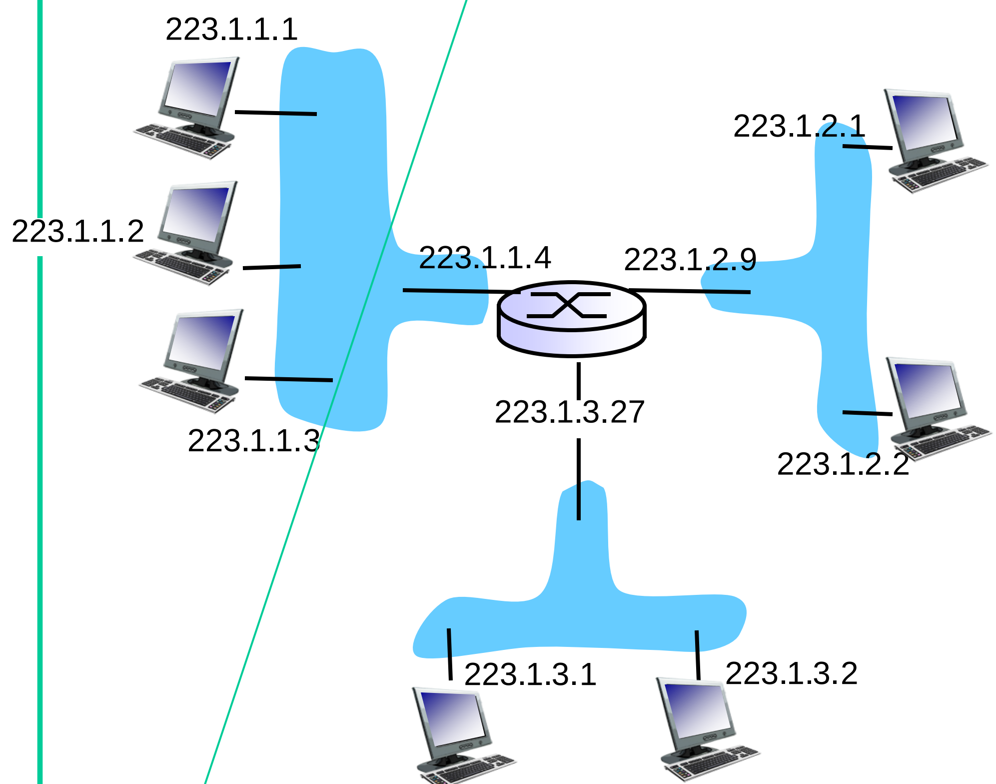
Last fragment has flag = 0



IP addressing

2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
128	64	32	16	8	4	2	1

- *IP address:* 32-bit network address (4 octets – bytes)
- IP addresses are unique and universal
- Address space: 2^{32} = 4,294,967,296
- *interface:* connection between host/router and physical link
  - router's typically have multiple interfaces
  - host typically has one or two interfaces (e.g., wired Ethernet, wireless 802.11)
- *IP addresses associated with each interface*

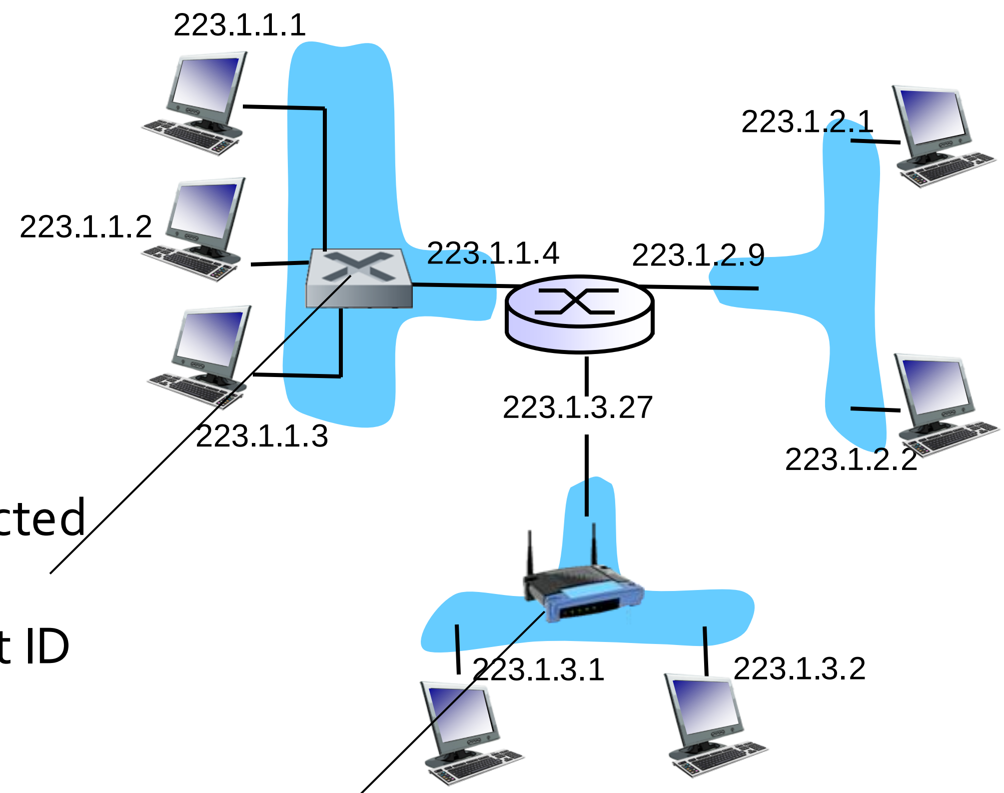


223.1.1.1 = 11011111 00000001 00000001 00000001

11011111	00000001	00000001	00000001
223	1	1	1

Dotted-decimal notation

Connection of interfaces



Wired Ethernet interfaces connected by Ethernet switches

IP address = Network ID and Host ID

Network ID (prefix) : 223.1.1.x

Host ID (postfix): identifies the interface of the network connection.

Wireless WiFi interfaces connected by WiFi base station

Classful Addressing

2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
128	64	32	16	8	4	2	1

Class	First Few Bits	First Byte Length	Prefix	Intent
A	0	1-126*	8	Very large networks
B	10	128-191	16	Large networks
C	110	192-223	24	Small networks
D	1110	224-239	NA	IP multicast
E	1111	240-255	NA	Experimental

*Addresses starting with 127 are reserved for IP traffic local to a host.

- Class A
  - 01111111 (127) reserved for loopback
  - 2^{31} or 2,147,483,648 class A complete IP addresses
  - 2^7 =128 blocks (network addresses)
  - Valid Range 1.x.x.x to 126.x.x.x (126 valid blocks)
- Class B
  - Range 128.x.x.x to 191.x.x.x
  - 2^{30} class B complete IP addresses
  - 2^{14}=16384 blocks (network addresses)

Class C
- Range 192.x.x.x to 223.x.x.x
- 2^{29} Class C complete IP addresses
- 2^{21}=2097152 blocks (network addresses)

Class D
- Multicast addresses
- No network/host hierarchy

Classful IP is wasteful, obsolete, and replaced by classless addressing

2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
128	64	32	16	8	4	2	1

Classless Addressing (CIDR)

- Classless Inter-Domain Routing - Prefix/host boundary can be anywhere, Less wasteful
- Address block is granted to an entity based on its size and nature
- Mask is used to define a block of addresses.
  - 32 bit number with n leftmost bits are ones
  - E.g. a.b.c.d/x → a.b.c.d defines one of the addresses and the /x defines the mask, 205.16.37.39/28 → 11001101 00010000 00100101 0010|0111, if we set the right most 32-28 bits to 0 we get: 11001101 00010000 00100101 0010|0000 : 205.16.37.32, and the last address of the block is: 205.16.37.47 (right most 4 bits: 1111)
  - The address and the /n (slash) notation completely define the whole block
  - The first address in a block is normally assigned to the router interface that connects to the Internet. It is used as the network address that represents the organization to the rest of the world
- Hierarchy: (408) 864 - 8902
  Area code Exchange office Subscriber
- No subnetting: Network prefix (28 bits) and host address (4 bits) 2-level hierarchy
- 3 level hierarchy: subnetting

Subnetting

2^7 2^6 2^5 2^4 2^3 2^2 2^1 2^0

128 64 32 16 8 4 2 1

3 – level hierarchy:

- Using the block of addresses, a cluster of networks (subnets) are created and divide addresses between different subnets. Benefits:
  - Overall traffic is reduced and performance enhanced
  - Smaller networks to manage and trouble shoot
  - Increase manager control over the address space
  - Reduce routing table entries and size
- Outside, the organization network is one entity defined by the network prefix (ID)
- Inside, the organization has several subnets
- E.g. A block of 17.12.40.0/26 is assigned to an organization
  - How many addresses: 64
  - Subnet 1 given 32 addresses → subnet mask = 27
  - Subnet 2 given 16 addresses → subnet mask = 28
  - Subnet 3 given 16 addresses → subnet mask = 28

Subnet1:

- Network prefix – 26 bits
- Subnet prefix – 1 bits
- Host addresses – 5 bits

Subnet2, Subnet 3:

- Network prefix – 26 bits
- Subnet prefix – 2 bit
- Host addresses – 4 bits

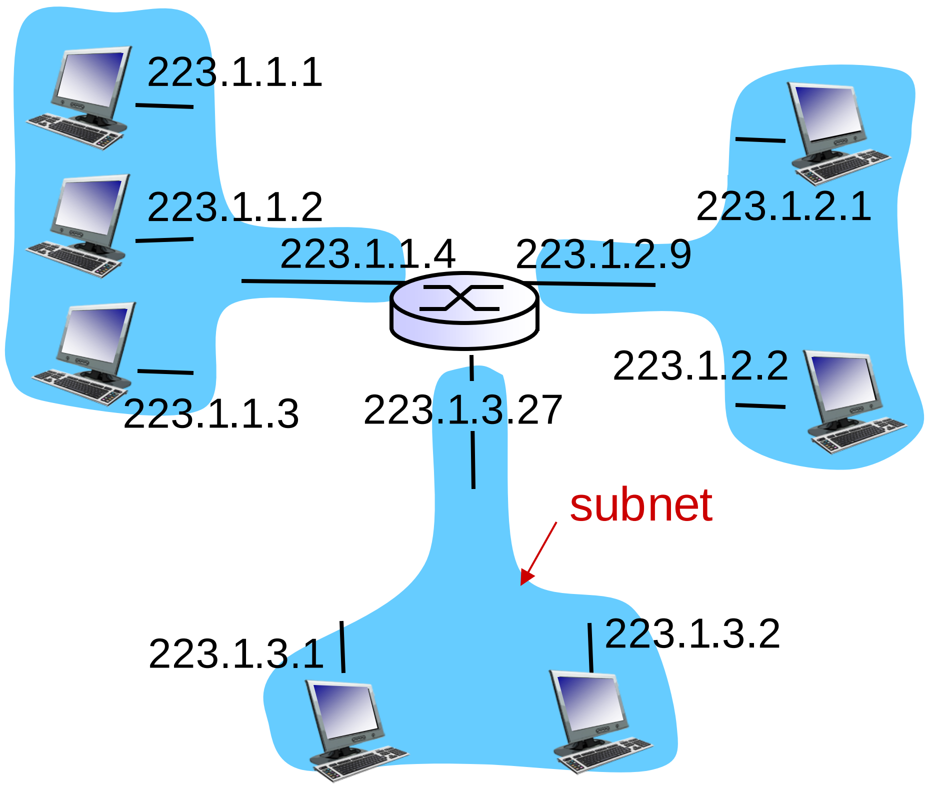
Subnets

IP address:

- subnet part - high order bits
- host part - low order bits

Subnet ?

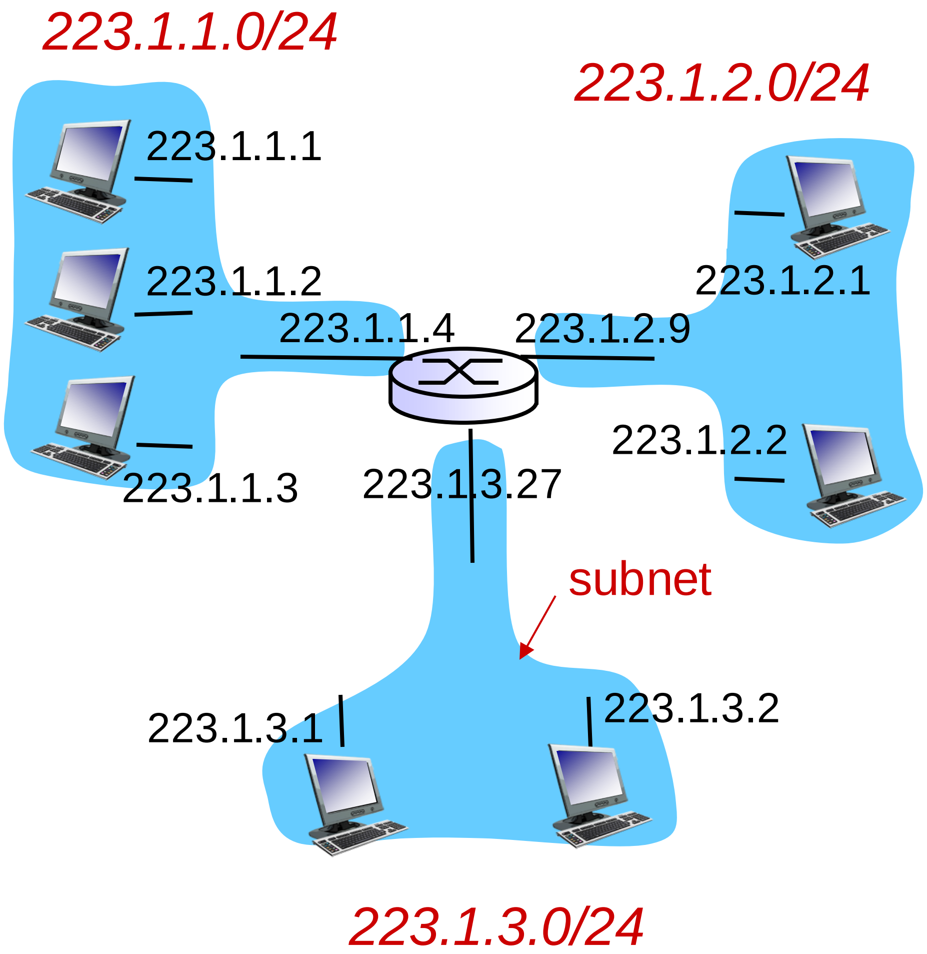
- device interfaces with same subnet part of IP address
- can physically reach each other *without intervening router*



network consisting of 3 subnets

Subnets

- to determine the subnets, detach each interface from its host or router, creating islands of isolated networks
- each isolated network is called a *subnet*

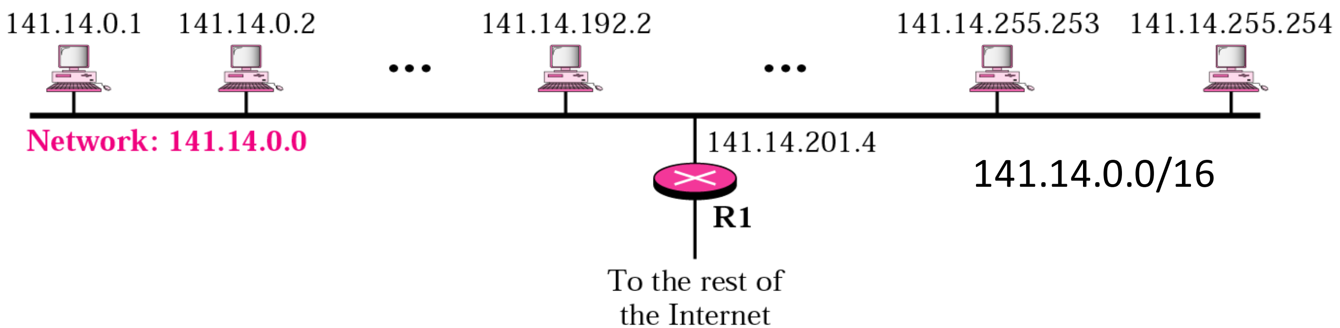


subnet mask: /24

Example 1

IPv4: 32 bit address space - dotted decimal notation

- Network ID (Prefix) and /n mask
- No subnetting – two level hierarchy (network ID and host) – too many hosts on same LAN



- Subnetting – 3-level hierarch: setup a cluster of networks (subnets)
  - Overall traffic is reduced and performance enhanced
  - Smaller networks to manage and trouble shoot
  - Increase manager control over the address space
  - Reduce routing table entries and size

* Source: Behrouz Forouzan, *Data Communications and Networking*, 4th Edition, McGraw-Hill

2^7 2^6 2^5 2^4 2^3 2^2 2^1 2^0

128 64 32 16 8 4 2 1

Example 1 network with subnetting

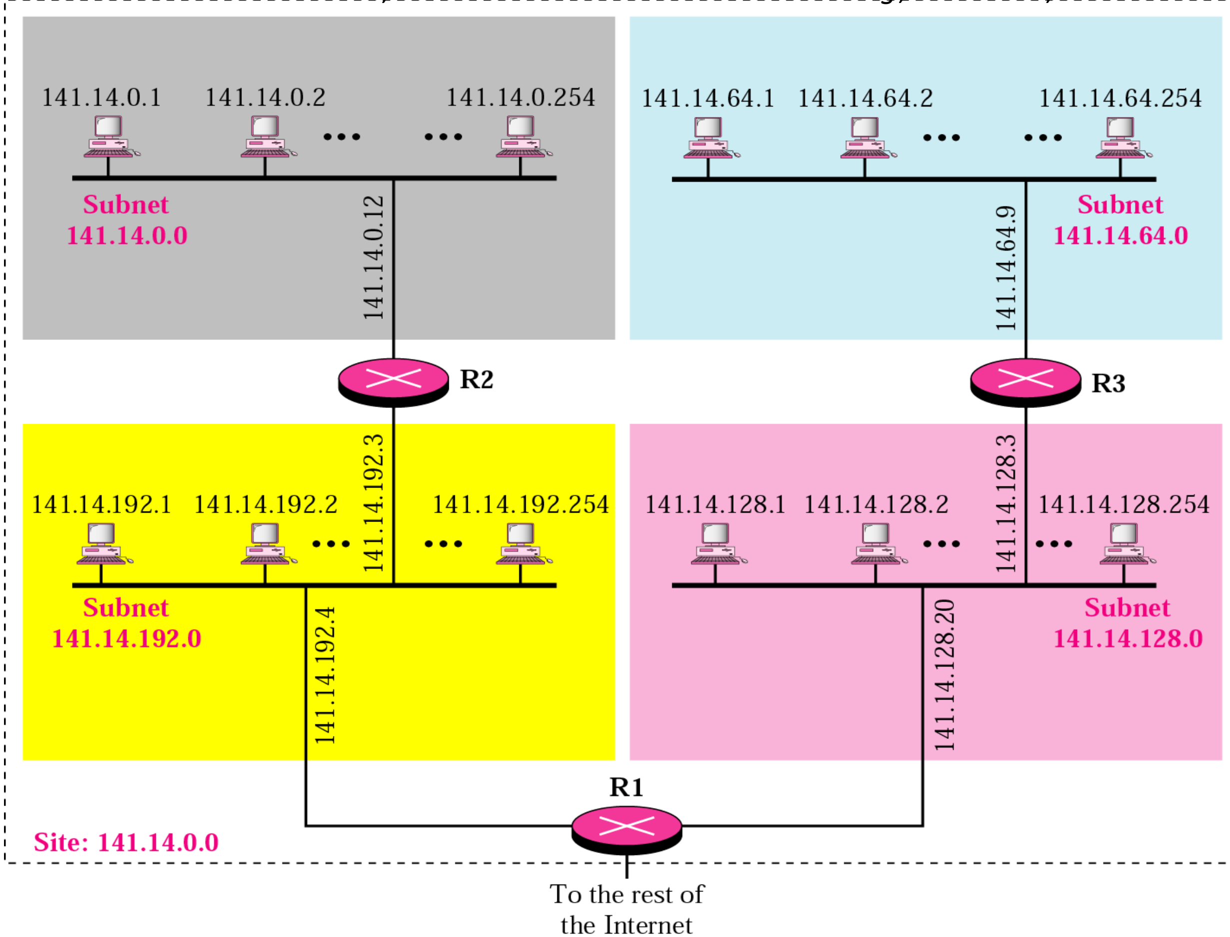
3-level hierarchy

- site: 141.14.0.0
- subnet 141.14.0.0
- subnet 141.14.64.0
- subnet 141.14.128.0
- subnet 141.14.192.0
- Routers will use subnet mask /18

- Mask is often written as 1_s:

/18 → 255.255.192.0

Source: Behrouz Forouzan, *Data Communications and Networking*, 4th Edition, McGraw-Hill



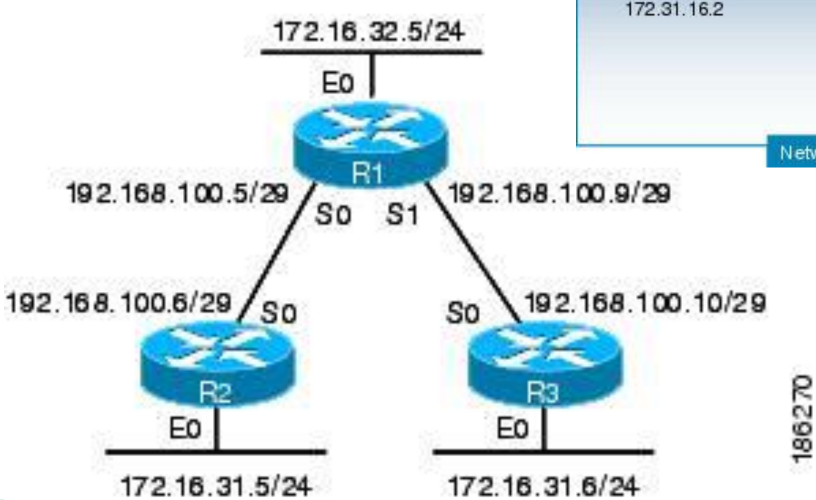
141.14. | 0000 0000 0000 0000 → Subnet prefix: 00, 01, 10, 11 (0, 64, 128, 192)

2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
128	64	32	16	8	4	2	1

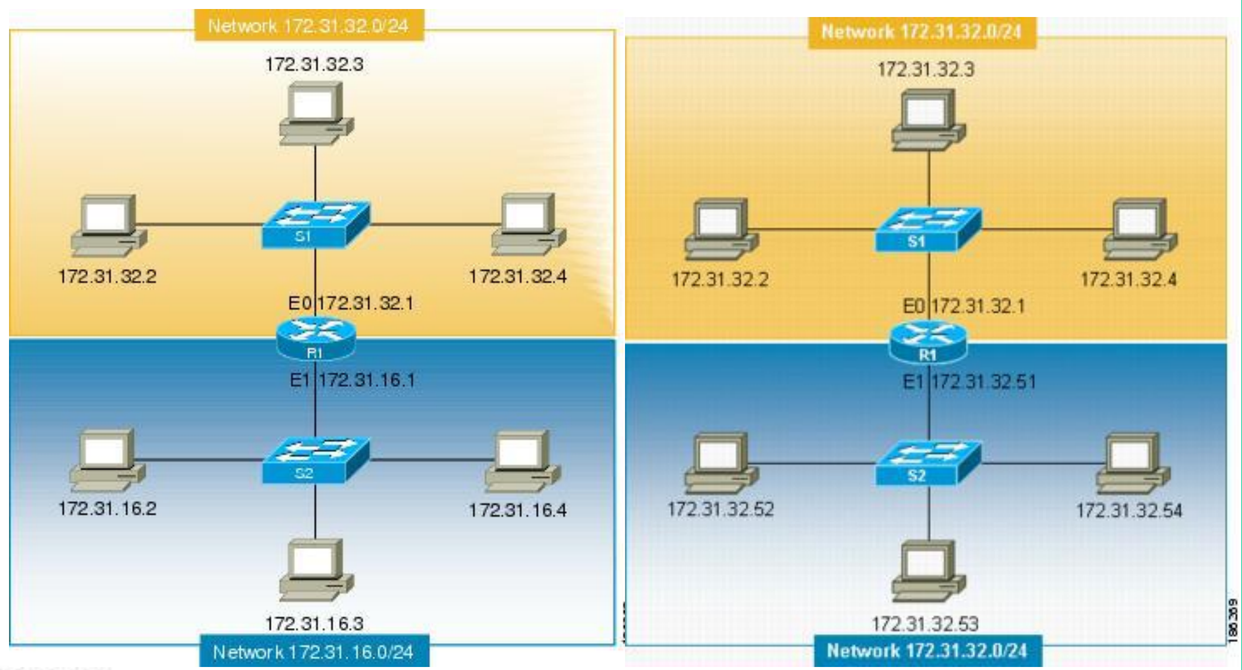
Example 3

```
Router(config)#
interface
   FastEthernet0/1
Router(config)#
ip address 172.31.16.1
   255.255.255.0
```

* practice: router takes 1st address in network ID and broadcast for (1….)



Source: IP Addressing: IPv4 Addressing Configuration Guide, Cisco IOS XE Release 3S



Routing Table for incorrectly Configured Network

Interface Ethernet 0	Interface Ethernet 1
172.31.32.0/24 (Con)	172.31.32.0/24 (Con)

Routing Table for a Correctly Configured Network

Interface Ethernet 0	Interface Ethernet 1
172.31.32.0/24 (Con)	172.31.16.0/24 (Con)

Private Addressing

- Internet authorities have reserved three sets of addresses as private addresses:
  - 10.0.0.0 – 10.255.255.255
  - 172.16.0.0 – 172.31.255.255
  - 192.168.0.0 – 192.168.255.255
- Unique inside the organization and not globally
- No router forwards a packet that has one of these addresses as the destination address

Summary

Today:

- IP datagram format and details
- IP addressing
- Classful addressing
- Classless addressing
- Subnetting

Canvas discussion:

- Reflection
- Exit ticket

Next time:

- read 4.3.4 (NAT and DHCP), 4.3.5 (IPv6) and 4.4 (SDN) of K&R
- follow on Canvas! material and announcements

Any questions?