

CC231

Introduction to Networks

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Internet Protocol Suite

Outline

- Internet Protocol Suite

TCP/IP: The Big Picture ^{1/10}

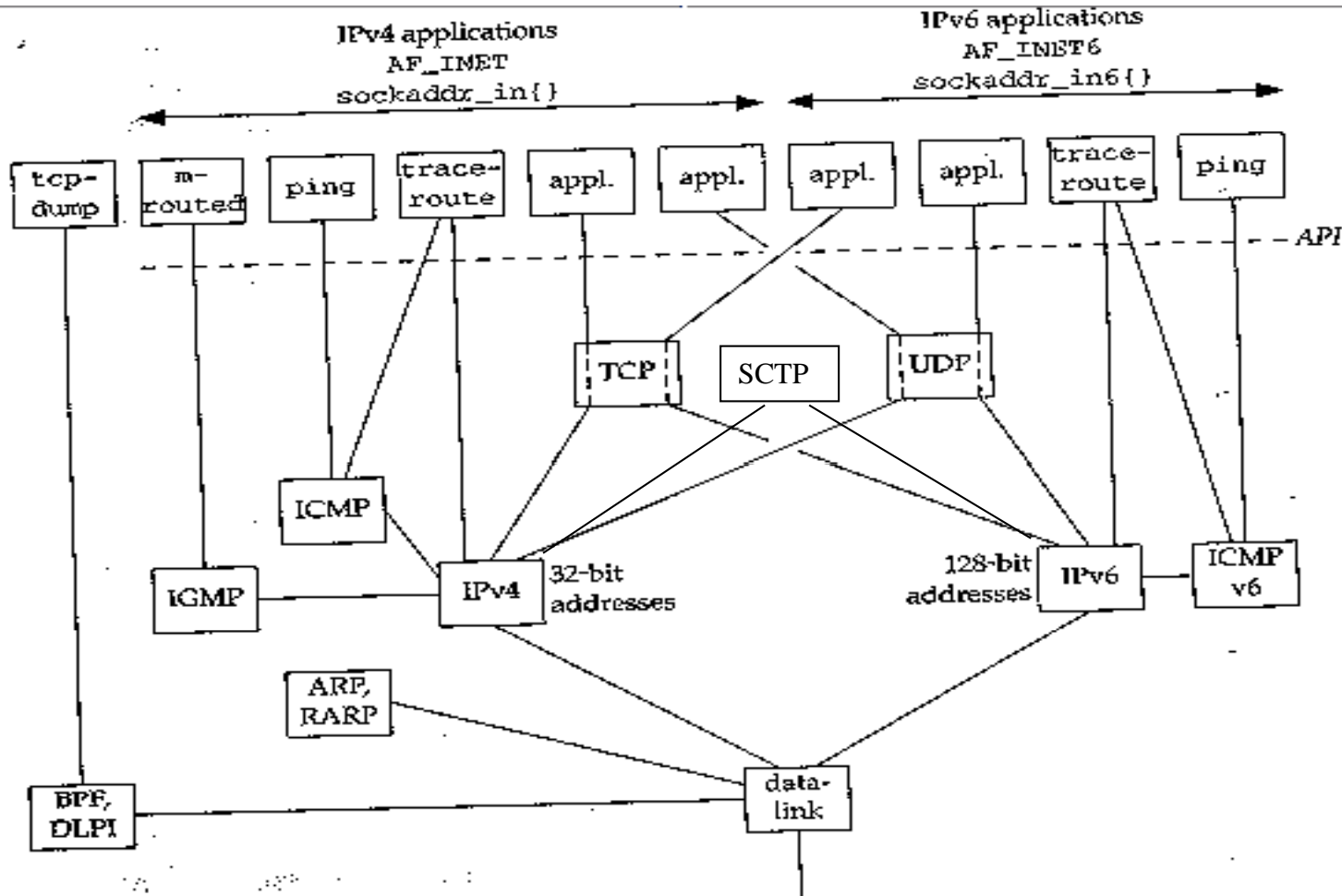


Figure 2.1 Overview of TCP/IP protocols.

TCP/IP: The Big Picture 2/10

Network Layer

IP: Internet Protocol (IPv4 and IPv6)

- Unreliable service
- Performs routing (Supported by routing protocols, e.g., BGP)
- Provide Internet-wide addressing (logical addressing)
- Fragment datagrams, as needed for underlying network

ICMP: Internet Control Message Protocol

- Handles error and control information between routers and hosts
- ICMP messages generated and processed by networking software and not user processes

TCP/IP: The Big Picture 3/10

Network Layer

IGMP: Internet Group Management Protocol

- Used with multicasting

ARP: Address Resolution Protocol

- Maps an IP (network) address into a hardware (network interface) address (such as an Ethernet address)

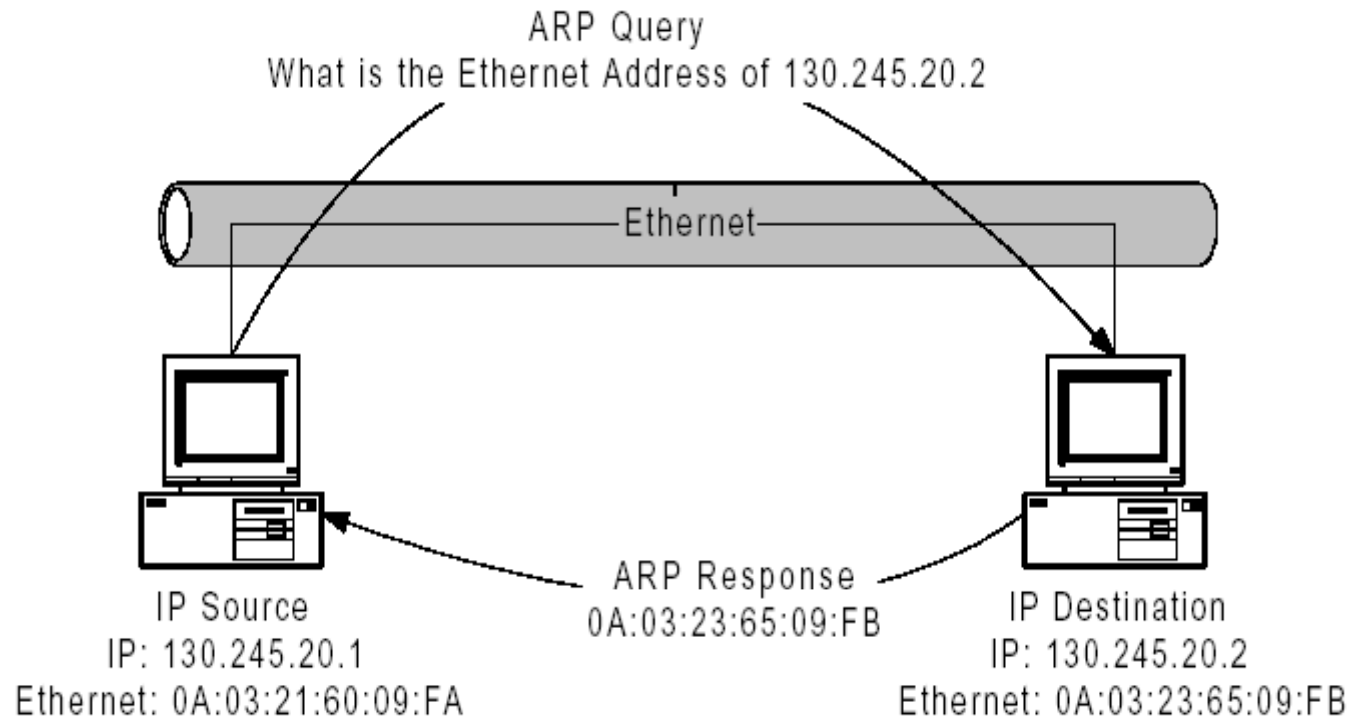
RARP: Reverse Address Resolution Protocol

- Maps a hardware address into an IP address

ICMPv6

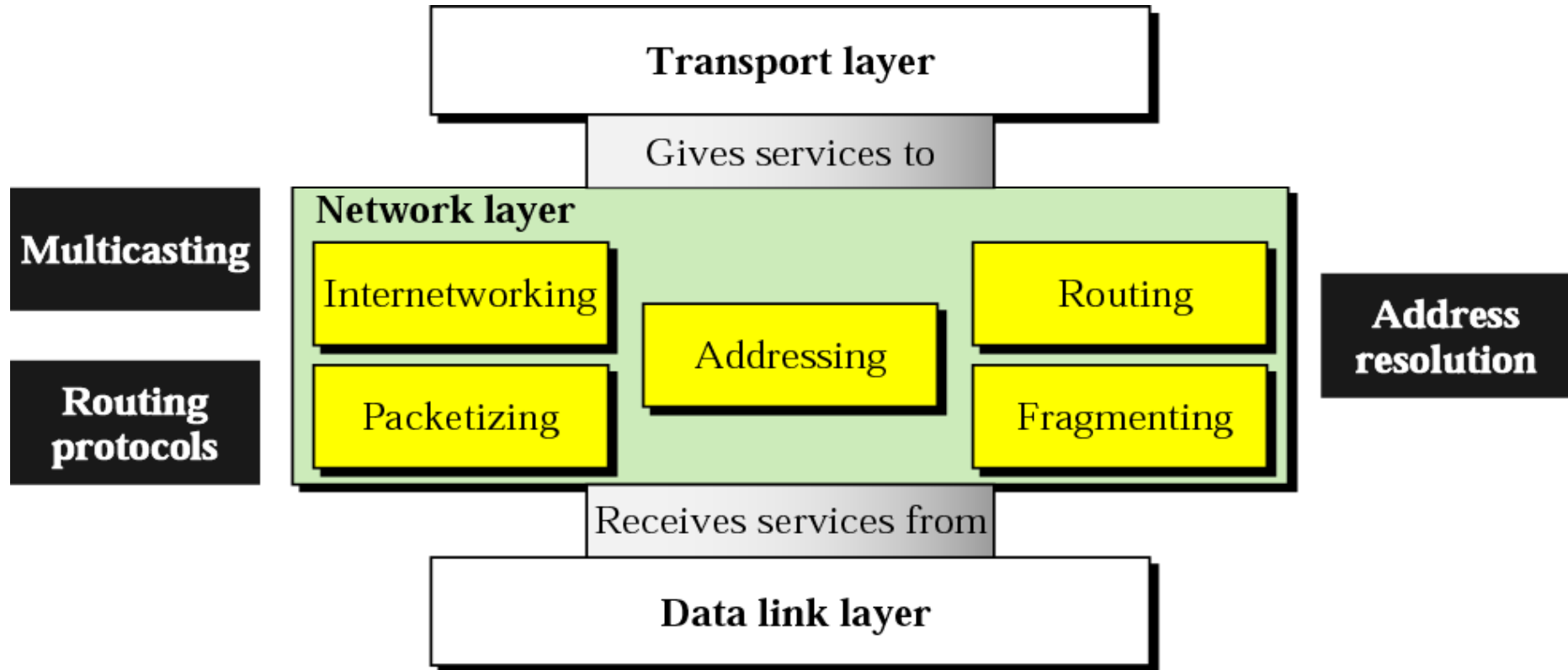
- Combines ICMPv4, IGMP, and ARP

TCP/IP: The Big Picture 4/10

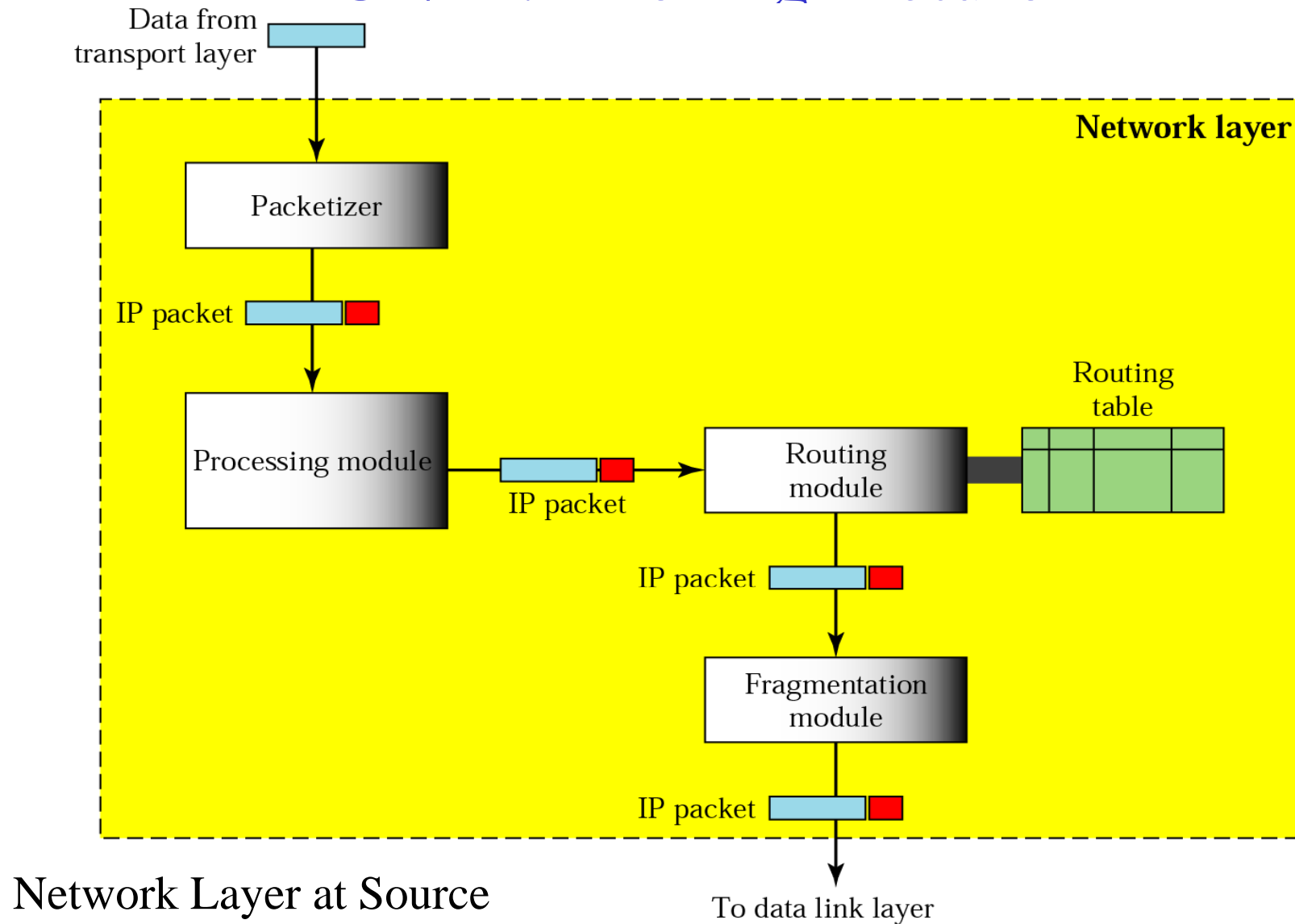


ARP (ARP responses are cached)

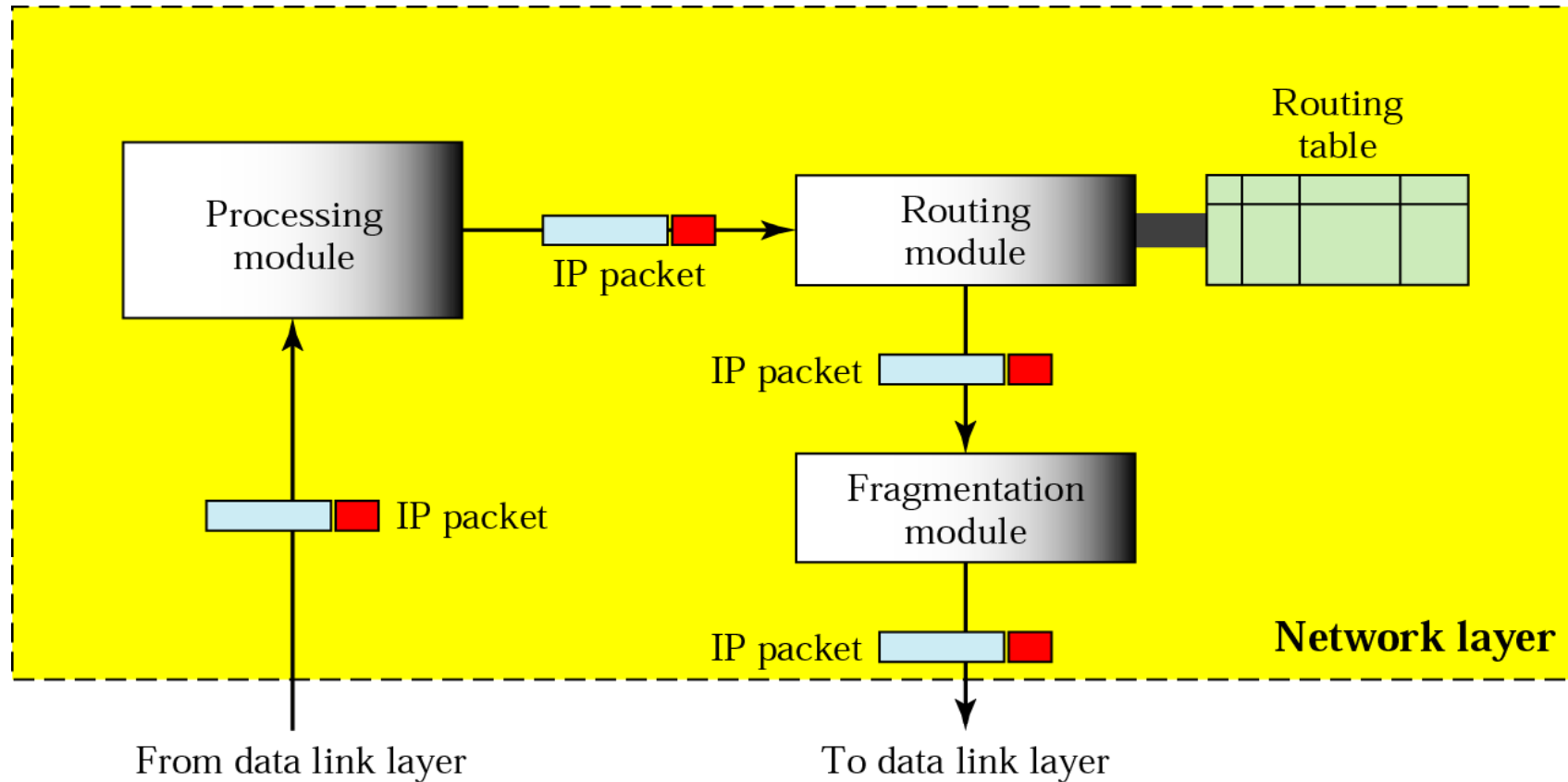
TCP/IP: The Big Picture 5/10



TCP/IP: The Big Picture 6/10

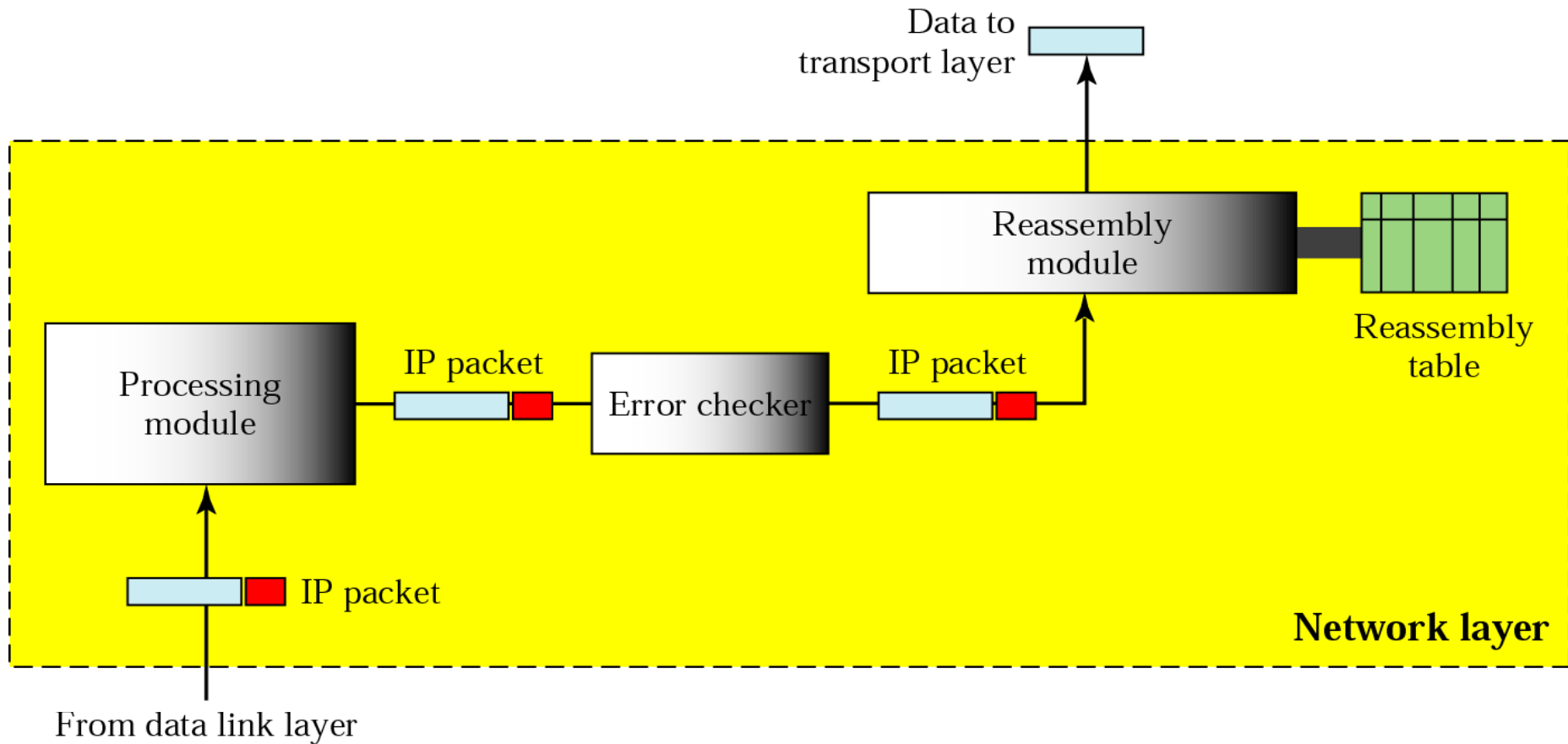


TCP/IP: The Big Picture 7/10



Network Layer at Router

TCP/IP: The Big Picture 8/10



Network Layer at Destination

TCP/IP: The Big Picture 9/10

Transport Layer

TCP: Transmission Control Protocol

- Byte stream transfer
- Reliable, connection-oriented service
- Point-to-point (one-to-one) service only

UDP: User Datagram Protocol

- Unreliable (“best effort”) datagram service
- Point-to-point, multicast (one-to-many), and
- broadcast (one-to-all)

TCP/IP: The Big Picture 10/10

Transport Layer

SCTP: Stream Control Transmission Protocol [RFC 2960]

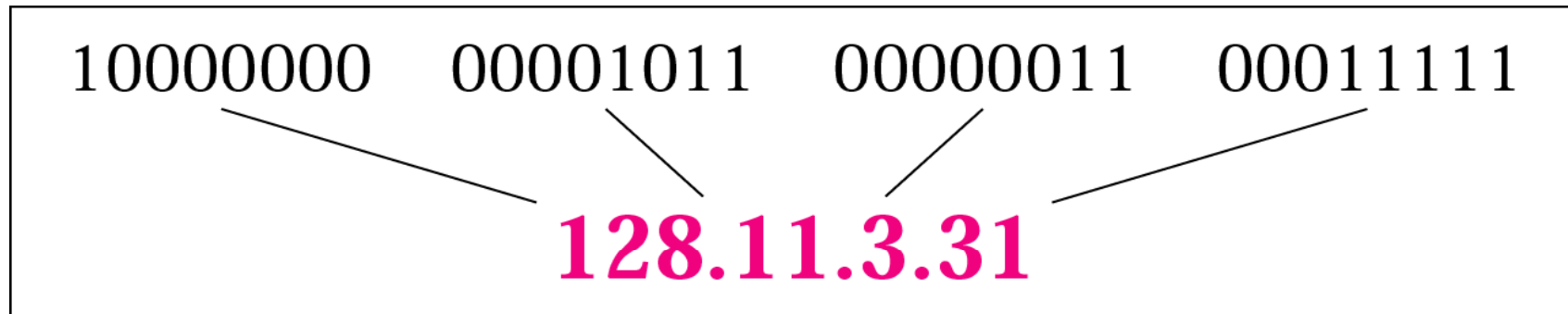
- Connection oriented
- Provides reliable full-duplex association
- Provides a message service
 - In TCP, a stream is a sequence of bytes
 - In SCTP, a stream is a sequence of messages
- Can use IPv4 and IPv6 on same association
 - Several streams within same association

Internetworking

- **Motivation** → Heterogeneity and scale
- IP is the glue that connects heterogeneous networks giving the illusion of a homogenous one
- **Features**
 - Best Effort Service Model
 - Global Addressing Scheme
- The Internet Protocol (IP) delivers datagrams across networks through routers (unreliable datagram service)
 - Datagrams (packets) may or may not be delivered
 - Datagrams may arrive at destination out of order
 - Datagrams may be arbitrarily delayed

IP Addressing ^{1/11}

- **Global** (public) IP addresses are *unique* (universal)
- **Private** IP addresses are not globally unique
 - No router will forward a packet that has a private IP address as a destination address
- Dotted decimal notation



IP Addressing ^{2/11}

Classful addressing

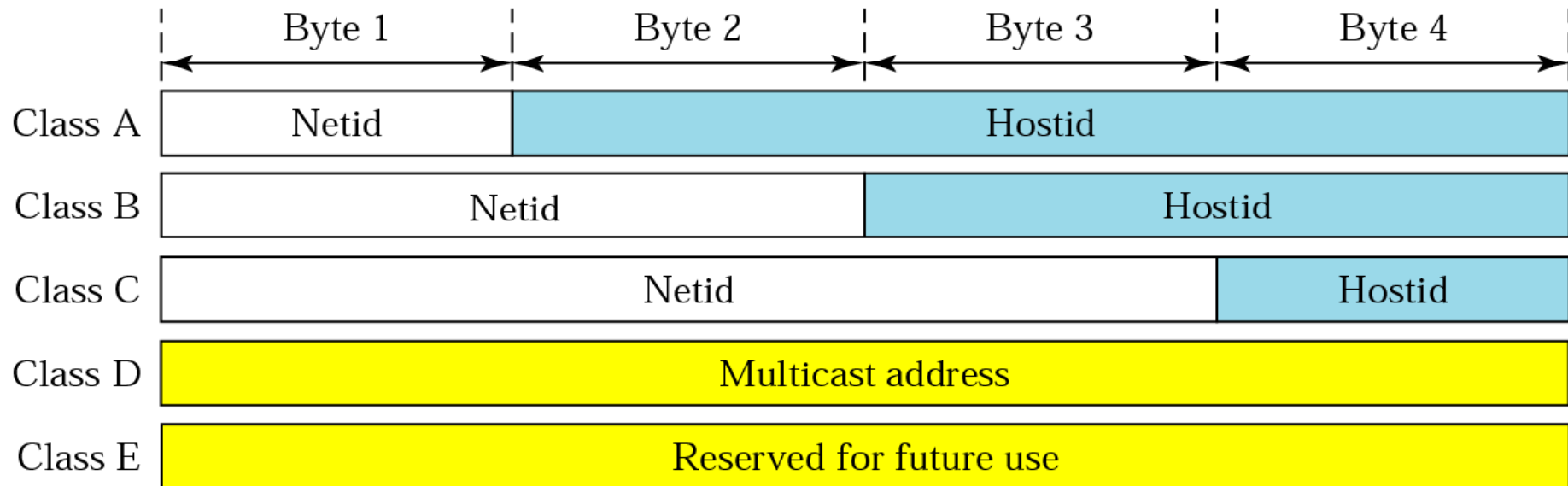
- Five classes: A, B, C, D, and E

	First byte	Second byte	Third byte	Fourth byte		First byte	Second byte	Third byte	Fourth byte
Class A	0				Class A	0 to 127			
Class B	10				Class B	128 to 191			
Class C	110				Class C	192 to 223			
Class D	1110				Class D	224 to 239			
Class E	1111				Class E	240 to 255			

IP Addressing ^{3/11}

Classful addressing

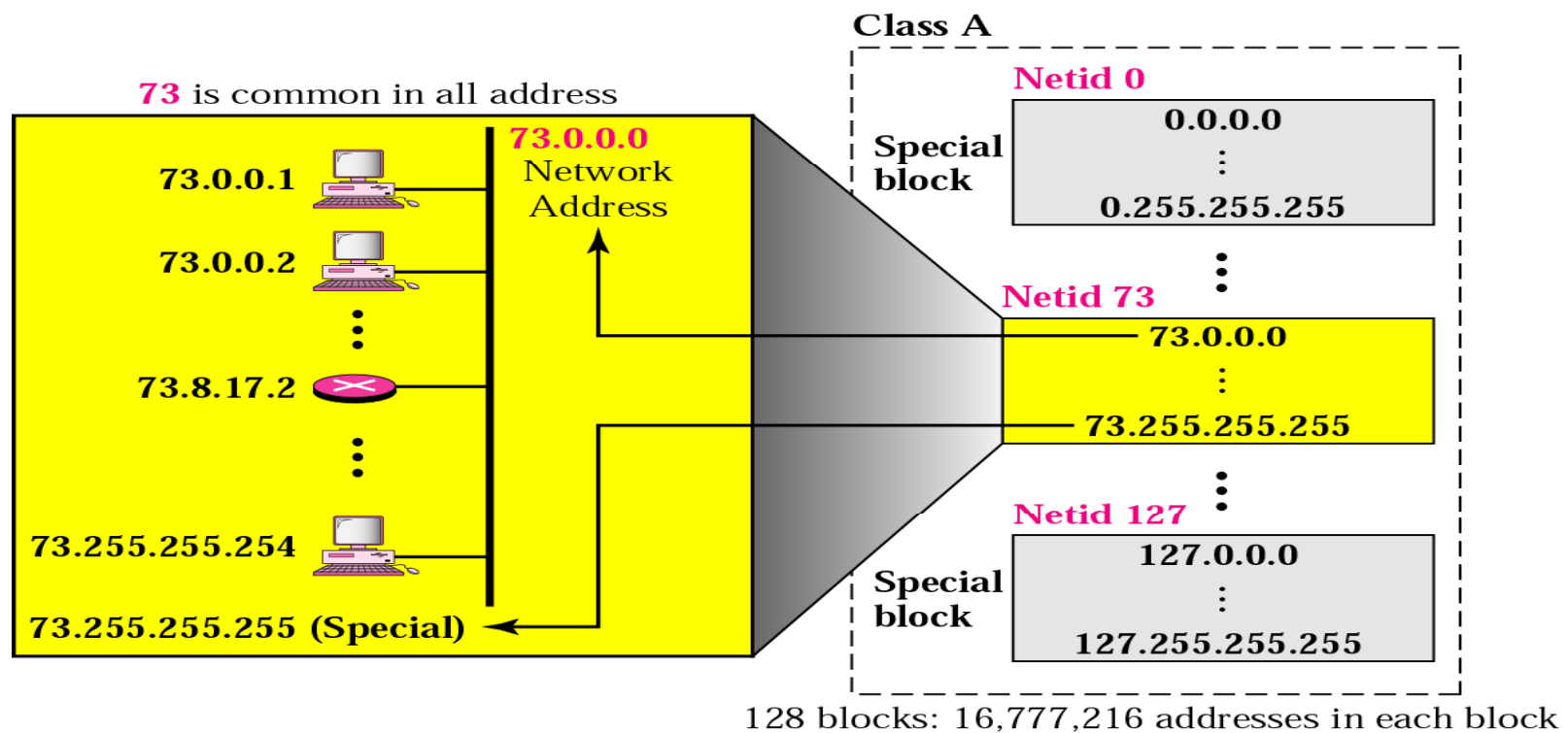
- *Hierarchical*: Network ID (*Netid*) and Host ID (*Hostid*)
- Each class is divided into a fixed number of blocks with each block having a fixed size



IP Addressing ^{4/11}

Classful addressing

- Class A divided into 128 blocks (each block a different *Netid*)
- First block 0.0.0.0 to 0.255.255.255
- 16,777,216 addresses in each block → *millions wasted*



IP Addressing ^{5/11}

Classful addressing

- Class B

- divided into 16,384 blocks
- 16 blocks for private addresses → only 16,368 blocks for assignment)
- Each block contains 65,536 addresses → *midsize organizations*

- Class C

- Divided into 2,097,152 blocks
- 256 for private addresses → 2,096,896 blocks for assignment
- Each block contains 256 addresses → *small organizations*

IP Addressing ^{6/11}

Classful addressing

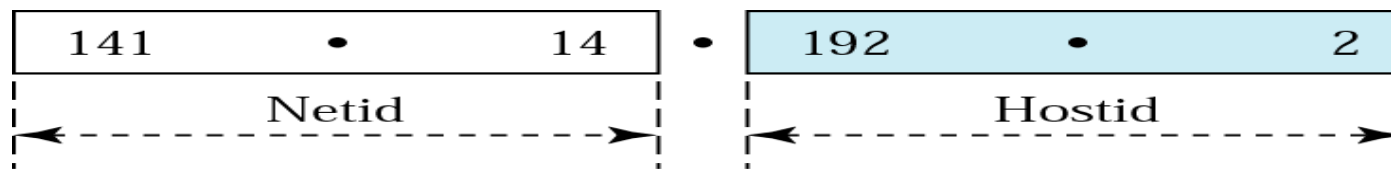
- *Network address*: an address that defines the network itself, e.g., 123.0.0.0 (class A), 141.14.0.0 (class B), and 221.45.71.0 (class C)
- Packets are routed to an organization based on the network address
- To find the network address → apply a *netmask* (default mask)
 - AND netmask with address
 - A netmask will retain the *Netid* of the block and sets the *Hostid* to 0s
 - e.g., 190.240.7.91 → class B, default mask is 255.255.0.0 → network address is 190.240.0.0
 - Could express address as 190.240.7.91/16 (*slash notation* → netmask has 1s in first 16 bits and 0s elsewhere)

IP Addressing 7/11

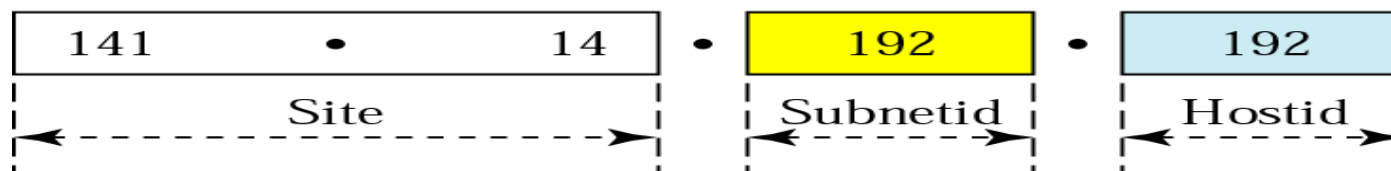
Classful addressing

• *Subnetting*

- Network address used to route packets to the network
- Outside world recognizes network, not individual hosts on the network (later reach host using the *Hostid*)
- Motivation for subnetting: *Assemble hosts into groups*
- Three levels of hierarchy: site, subnet, and host



a. Without subnetting



b. With subnetting

IP Addressing ^{8/11}

Classful addressing

• *Subnetting*

- A packet reaches a site based on the network address (using the netmask)
- Routers inside the organization route based on subnetwork address)
- **To find subnet address** → apply a subnet mask
 - ✓ AND subnet mask with address
 - ✓ e.g., 190.240.33.91 with /24 subnet mask (network address is 190.240.0.0 and subnet address is 190.240.33.0)
 - ✓ Can you figure out 190.240.33.91/19?

IP Addressing ^{9/11}

Broadcast Addresses

- Special addresses used for broadcasting
 - **Directed broadcast**
 - ✓ All 1's in *Hostid*
 - ✓ All hosts on a specified network (or subnet)
 - **Limited broadcast**
 - ✓ all 1's (network and *Hostid*)
 - ✓ Picked up by all other nodes on the LAN
 - ✓ Not forwarded
- Example: broadcasting for 128.173.92.96
 - Directed broadcast (using subnet): 128.173.255.255
 - Limited broadcast: 255.255.255.255

IP Addressing 10/11

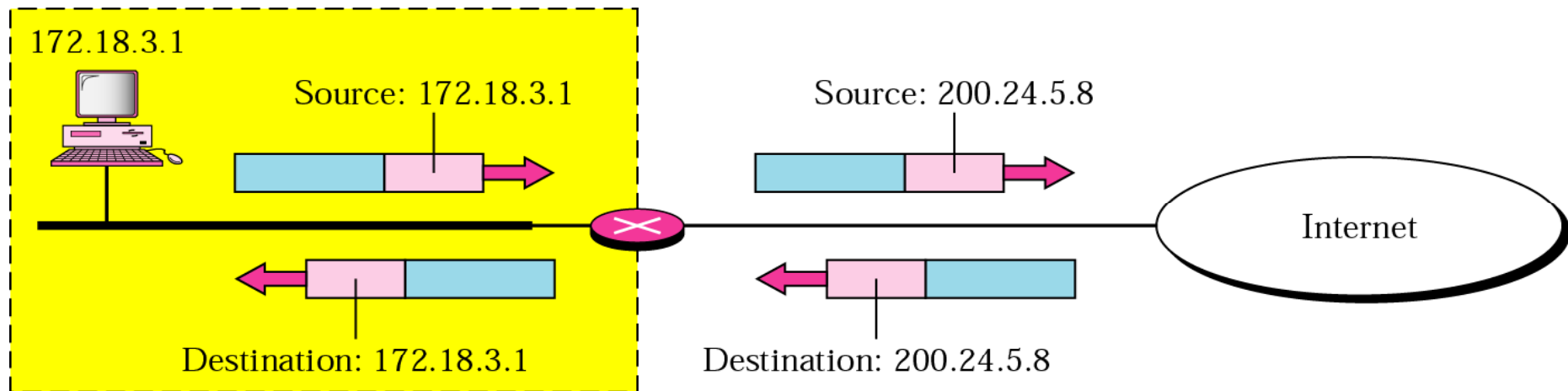
Classless addressing

- Classful addressing problematic
 - Fixed block size and address waste
 - ISPs are granted several class B or C blocks and then subdivide range between customers
- In 1996, *classless addressing* introduced
 - *Variable-length blocks that belong to no class*
 - Organization given first address and mask
 - Can use subnets
 - Classless Inter-Domain Routing (CIDR)

IP Addressing 11/11

Network Address Translation (NAT)

- Use a number of private (internal) addresses (home users and small businesses) when assigned ONE (or a small set) externally
 - NAT router replaces source address in outgoing packets with global NAT address
 - NAT router replaces destination address in incoming packets with appropriate private address
- The need for PAT (Port Address Translation)

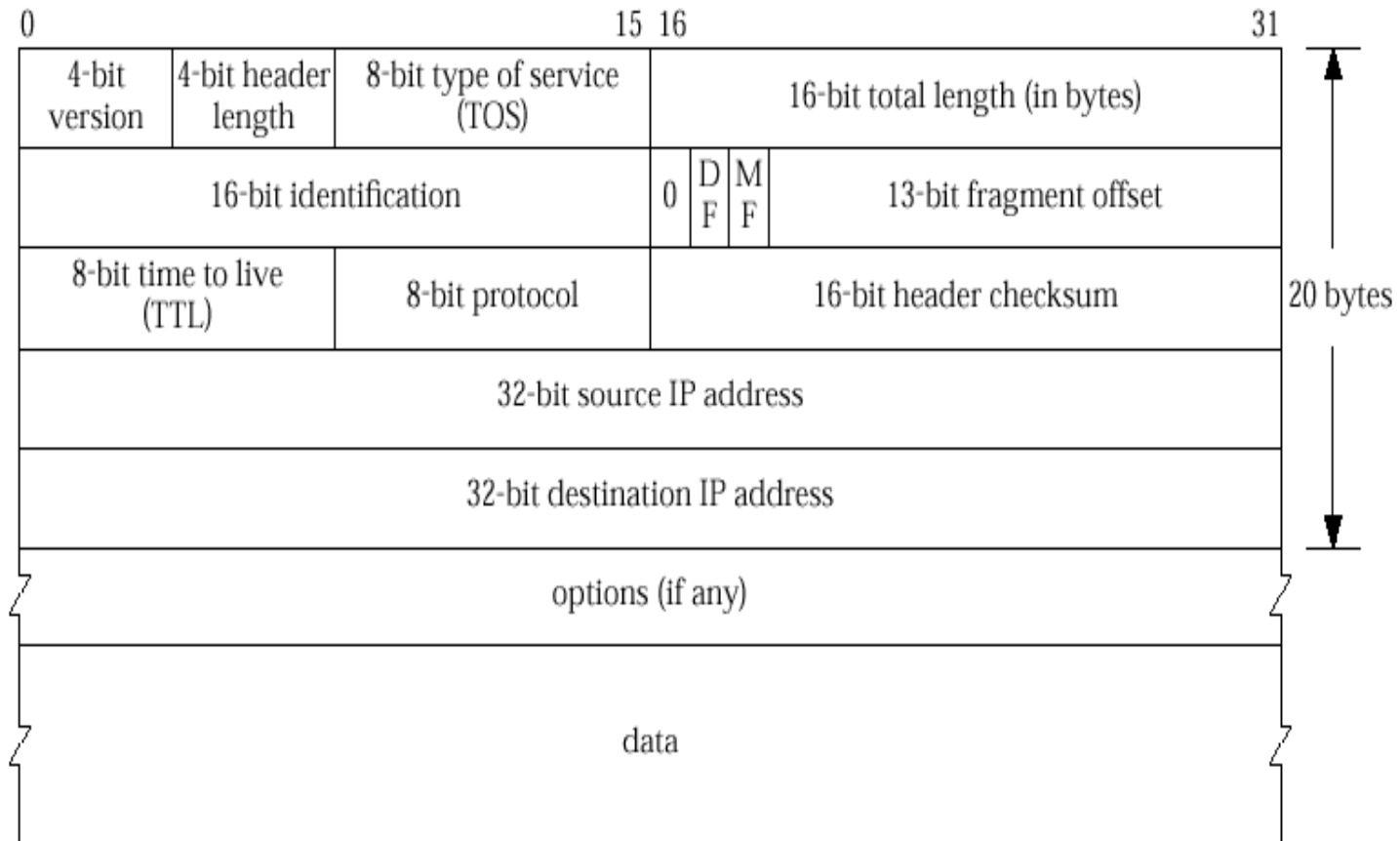


IP Datagrams

- IP datagrams include
 - Header, minimum size of 20 bytes
 - Data
- Datagram size
 - Less than or equal to *maximum transmission unit* (MTU) of the underlying network (Ethernet MTU is 1,500 bytes)
 - *MTU is the maximum amount of data that a link-layer packet can carry*
- Fragmentation
 - Packets may need to be fragmented at intermediate nodes if packet is too big for an intermediate network
 - ✓ *Path MTU less than link MTU at sender*
 - ✓ *Remember in IPv4, hosts and routers fragment datagrams*
 - ✓ *In IPv6, only hosts perform fragmentation*
 - Receiver reassembles fragments to form entire IP packet

IP Datagram Format

IP Header



IP Header Fields ^{1/2}

- **Identification**: unique datagram identifier
- **Total Length**: length of this datagram + header, in bytes
 - Minimum datagram size in IPv4 is 576 bytes (in IPv6 → 1,500 bytes)
 - Use 576 (Minimum MTU) if path MTU unknown, or path MTU if on a connected network (datagram may be fragmented)
- **Internet Header Length**:
 - length of header in 32-bit words (+options)
 - Max is 15 allowing for sizes (header +options) of 60 bytes
- **Fragment Offset**: offset of fragment in this datagram in 8-byte units
- **Flags (DF and MF)**: indicate if last fragment, and If datagram should not be fragmented (**What happens if need to fragment and DF is set?**)
- **Time To Live**: maximum number of routers through which the datagram may pass
 - Decrement at each router
 - Used to prevent looping in the network
 - Also used to limit scope of multicast datagrams

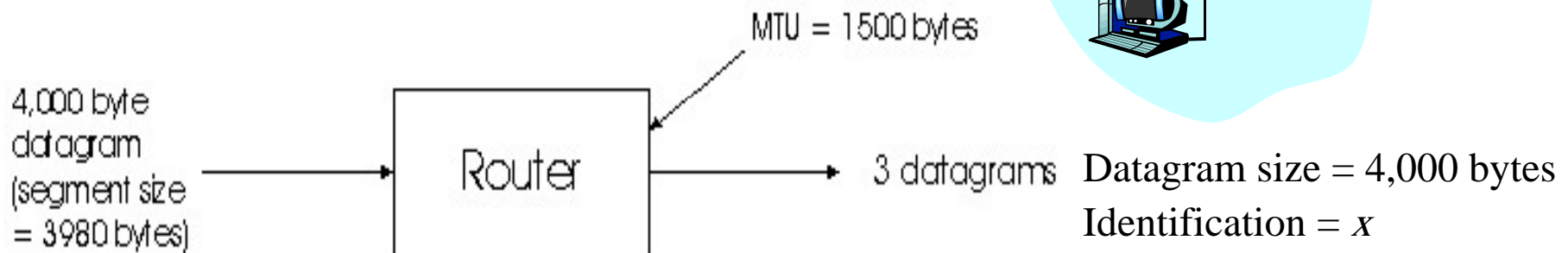
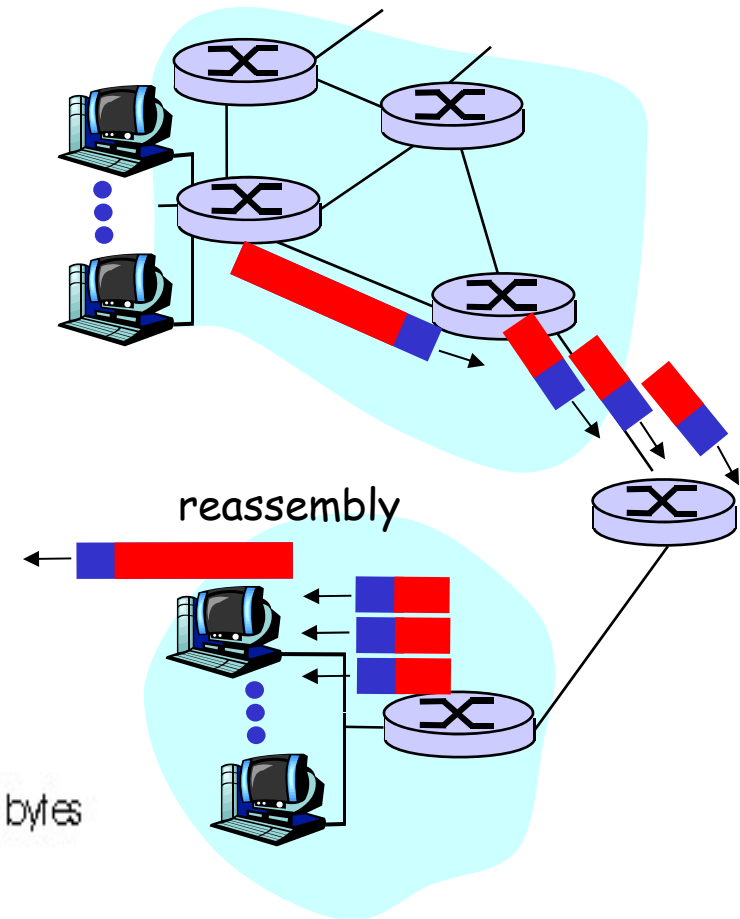
IP Header Fields 2/2

- **Protocol**: identifies higher level protocol that provided data
- **Version**: IP version identifier (currently 4)
- **Type of Service**: (historical)
 - Maximize throughput, minimize delay, maximize reliability, minimize cost (no guarantees, though)
 - Now replaced with 6-bit Differential Services Code Point and 2-bit Explicit Congestion Notification
- **Header Checksum**: checksum over header (protects addresses, lengths, etc.) → 16-bit 1's complement of 1's complement sum of 16-bit
- **Source IP Address** and **Destination IP Address**
- **Options** (rarely used, may not be supported by routers)
 - Security and handling restrictions
 - Record route
 - Loose source routing (datagram passes through listed nodes and others)
 - Strict source routing (datagram must pass through only each listed node)

IPv4 Fragmentation by Routers Example ^{1/2}

• In adhering to **end-to-end** principle

- *If a router fragments a datagram, reassembly is only performed at destination*
- *Reassembly at routers would complicate network performance*



IPv4 Fragmentation by Routers Example ^{2/2}

1st fragment

- 1480 bytes in the data field of the IP datagram (total length = 1500)
- identification = x
- offset = 0 (meaning the data should be inserted beginning at byte 0)
- flag = 1 (meaning there is more)

2nd fragment

- 1480 bytes in the data field of the IP datagram (total length = 1500)
- identification = x
- offset = 1,480 (meaning the data should be inserted beginning at byte 1,480)
- flag = 1 (meaning there is more)

3rd fragment

- 1020 bytes (=3980-1480-1480) in the data field of the IP datagram (Total length = 1040)
- identification = x
- offset = 2,960 (meaning the data should be inserted beginning at byte 2,960)
- flag = 0 (meaning this is the last fragment)