Lecture 15: Network Layer – Data Plane II

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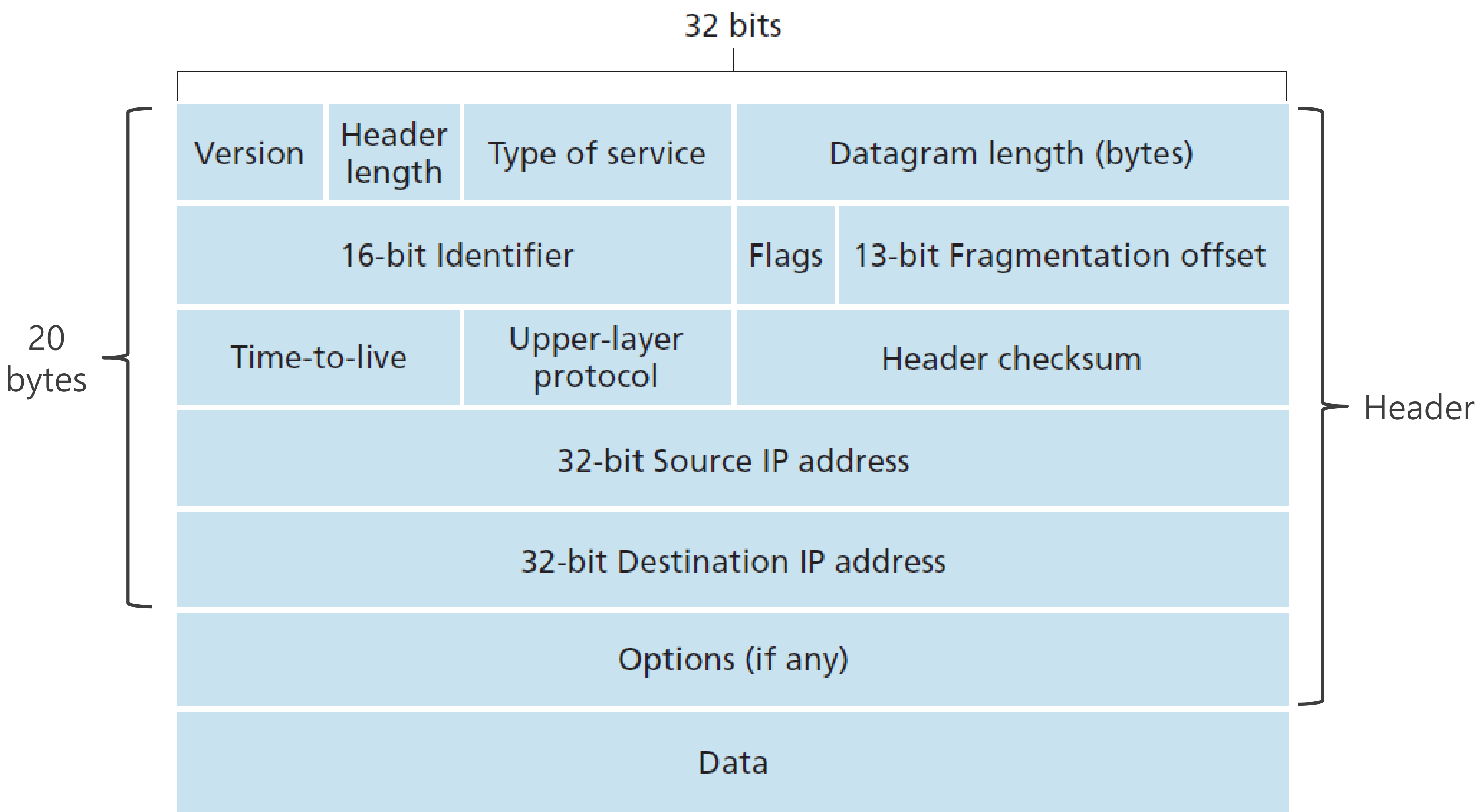
Contents of Chapter 4

- Overview of network layer
- What's inside a router?
- **The internet protocol (IP): IPv4, addressing, IPv6, and more**
  - IPv4 datagram format
  - IPv4 datagram fragmentation
  - IPv4 Addressing
    - Subnet, CIDR, DHCP
  - Network address translation (NAT)
  - IPv6
- Generalized forwarding and SDN

IPv4 Datagram Format



Key Fields in the IPv4 Datagram

- **Version number (4 bits)**
  - 4: IP version 4, 6: IP version 6
- **Header length (4 bits)**
  - The number of bytes in the header (mostly 20 bytes)
- **Type of service (TOS) (1 byte)**
  - Different types such as real-time traffic, non-real-time traffic
  - Mostly not implemented
- **Datagram length (2 bytes)**
  - The number of bytes in the header and the data (~65,535 bytes)
  - Rarely larger than 1,500 bytes

Key Fields in the IPv4 Datagram

- **Time-to-live (TTL) (1 bytes)**
  - Specify how long the datagram is allowed to *live* on the network
  - Decremented by one each time the datagram is processed by a router
  - If the TTL field reaches 0, a router must drop that datagram.
- **Protocol (1 bytes)**
  - Indicate the specific transport-layer protocol
    - E.g., 1 for ICMP, 6 for TCP, 17 for UDP
  - Typically used only when an IP datagram reaches its final destination

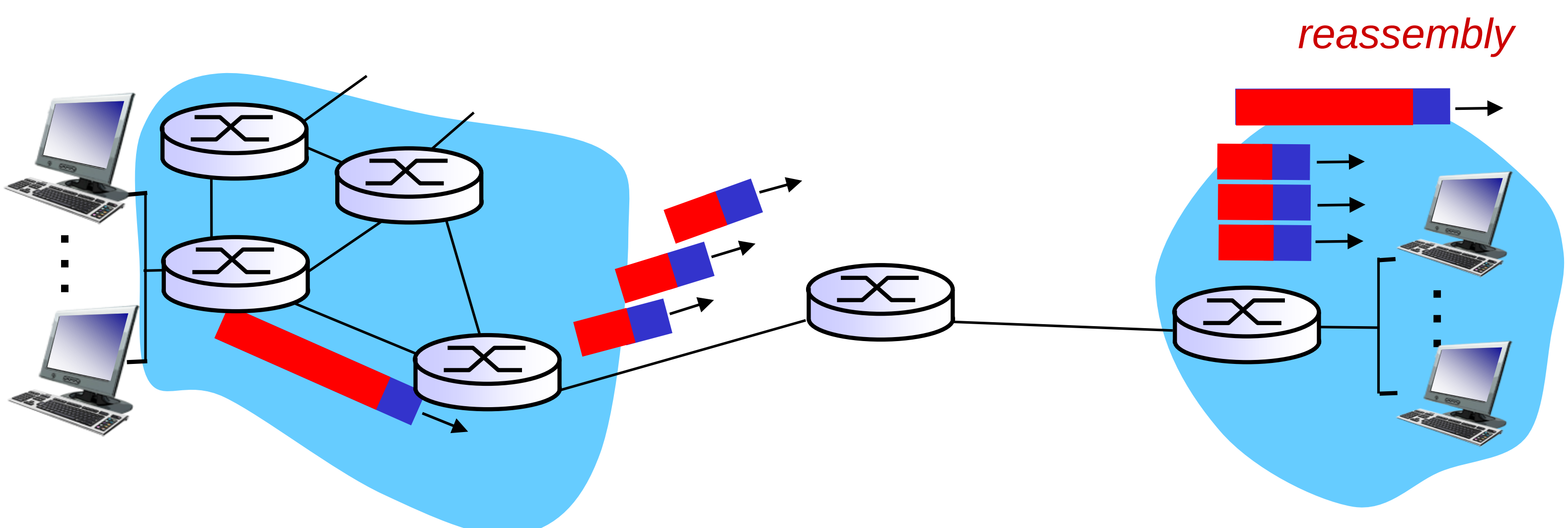
ICMP: Internet control message protocol

Key Fields in the IPv4 Datagram

- **Header checksum (2 bytes)**
  - Aid a router in detecting bit errors in a received IP datagram
  - Computed by treating each 2 bytes in the header as a number and summing these numbers using 1s complement arithmetic
  - 1s complement of this sum is stored
- **Source IP address (4 bytes)**
- **Destination IP address (4 bytes)**
- **Options (variable)**
  - Rarely used
- **Data (payload)**
  - Include the upper-layer data such as TCP segment, UDP segment

IPv4 Datagram Fragmentation

- **Maximum transmission unit (MTU)**
  - The maximum amount of data that a link-layer frame can carry
- **Link-layer protocols can have different MTUs.**
  - E.g., 1,500 bytes for Ethernet, 2304 bytes for WiFi
- **A router needs to fragment a datagram.**
- **Note: Datagram reassembly is done in the end systems**

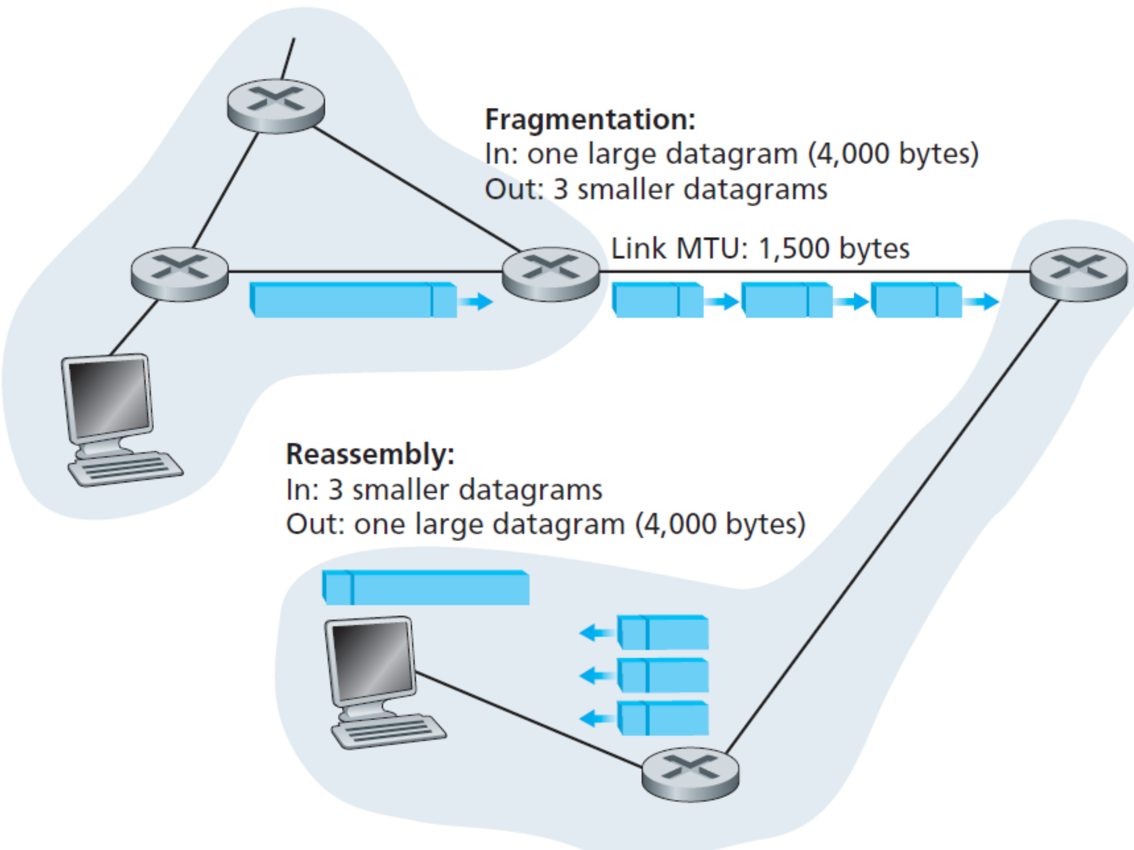


Header Fields for Fragmentation

- **Identifier (2 bytes)**
  - When a datagram is created, the sending host stamps the datagram with an identification number.
  - A fragment has the same identification number.
- **Flags (3 bits)**
  - The last fragment has a flag bit set to 0.
  - All the other fragments have this flag bit set to 1.
- **Fragmentation offset (13 bits) – unit of 8 bytes**
  - Specify the offset, or position, in the overall message where the data in this fragment goes.
  - Determine whether a fragment is missing
  - Reassemble the fragments in their proper order

IPv4 Datagram Fragmentation

- **Example of IP fragmentation and reassembly**
  - Sending a datagram of 4,000 bytes (20 bytes IP header + 3,980 bytes data)

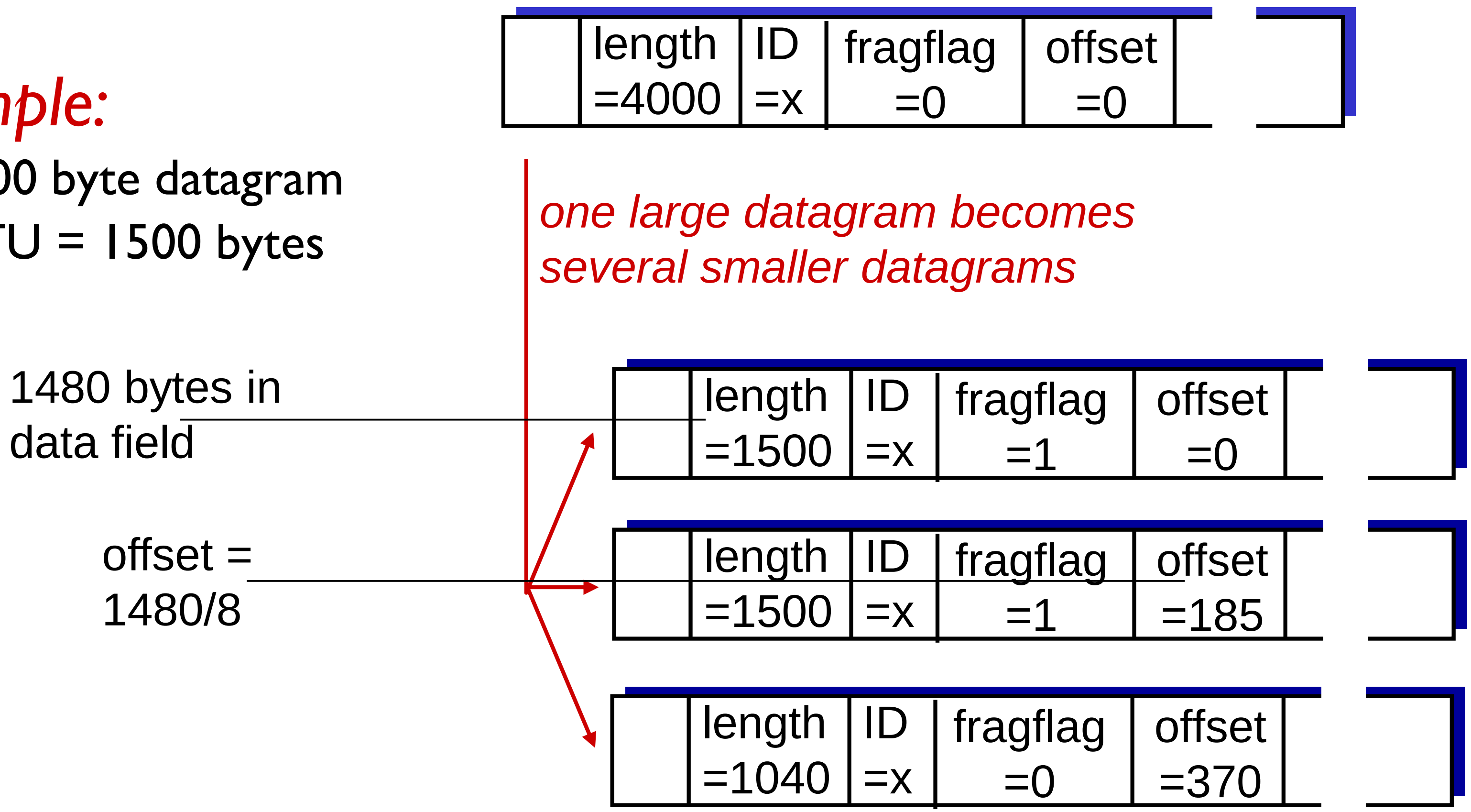


IPv4 Datagram Fragmentation

- Example of IP fragmentation and reassembly (cont'd)

example:

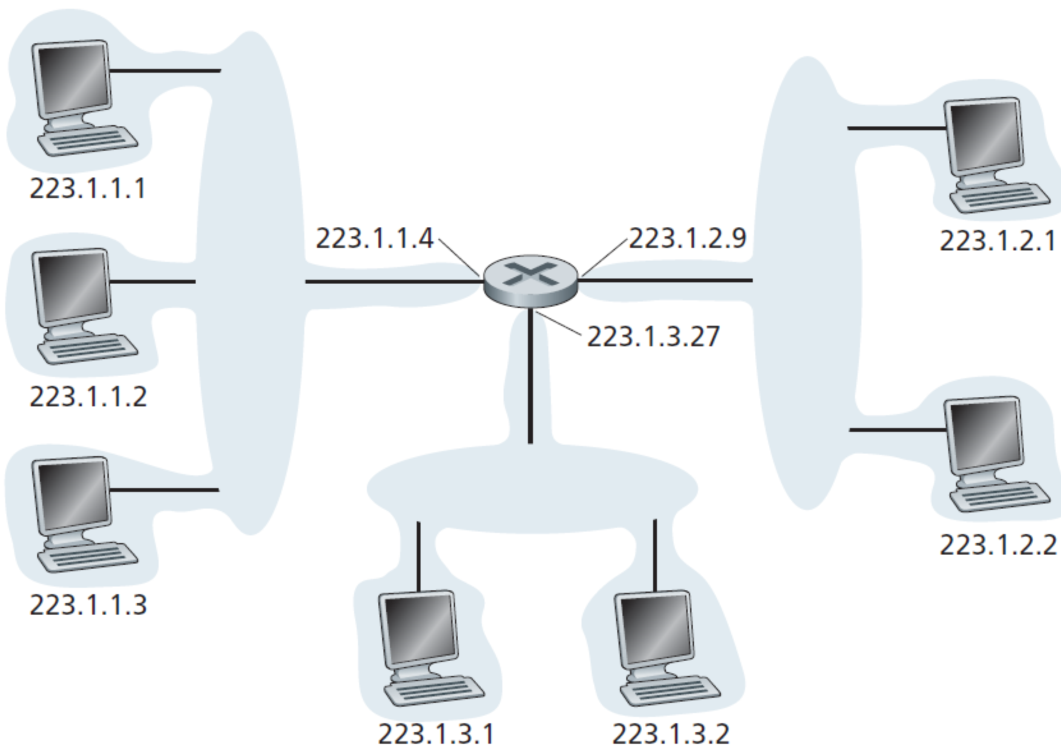
- 4000 byte datagram
- MTU = 1500 bytes



IPv4 Addressing

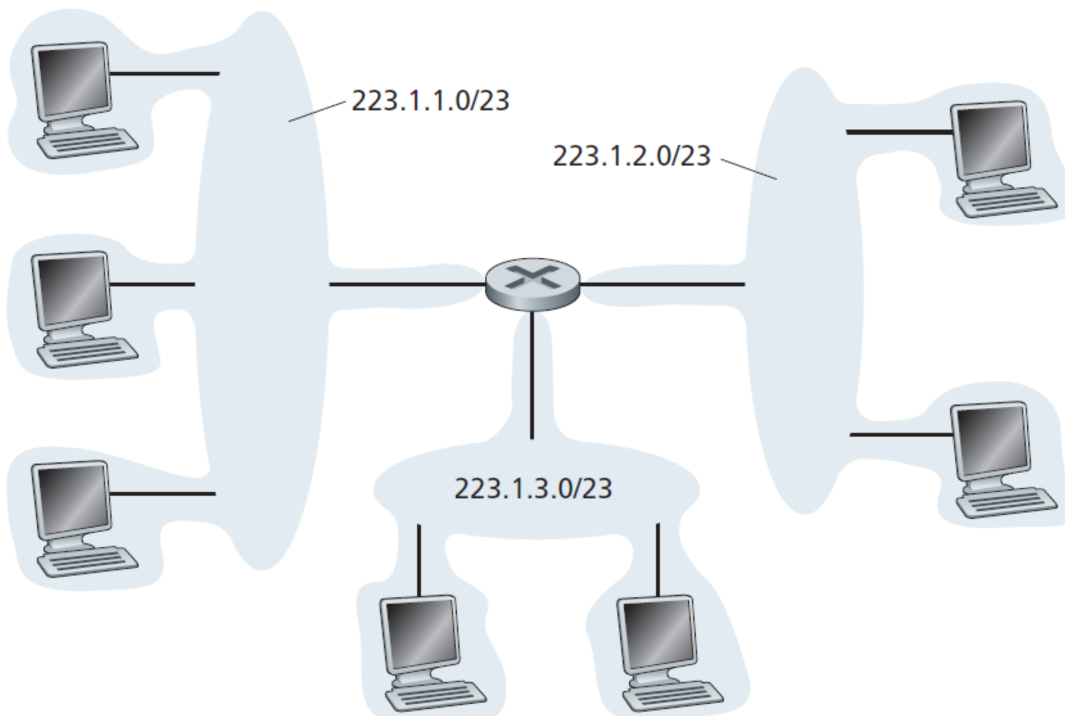
IPv4 address

- 32 bits long, typically written in dotted-decimal notation (e.g., 193.32.216.9)
- Associated with an interface, rather than with the host or router



IPv4 Addressing

- **Subnet**
  - A network interconnecting interfaces without a router



IPv4 Addressing

Subnet mask

- Indicate a portion for the subnet address in the IPv4 address
- Example
  - '24' means that the leftmost 24 bits define the subnet address.
  - '24' can be written as '255.255.255.0' equivalently.

subnet part ← → host part

11001000 00010111 00010000 00000000

200.23.16.0/24

IPv4 Addressing

- How many subnets here?