National University of Computer & Emerging Sciences

CS 3001 - COMPUTER NETWORKS

Lecture 16

Chapter 4

18th October, 2022

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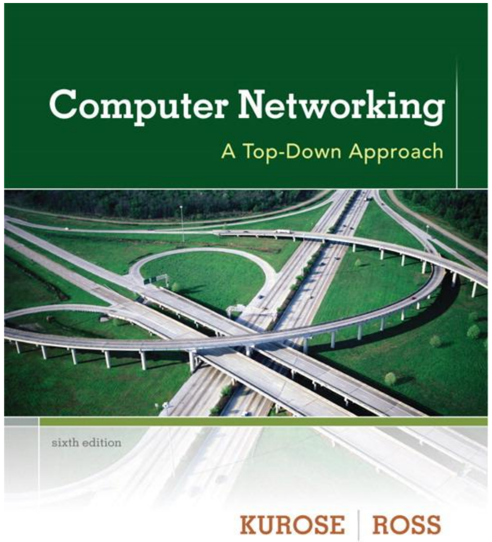
Office Hours: 02:30 pm till 06:00 pm (Every Tuesday & Thursday)

Chapter 4
Network Layer



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- If you use these slides (e.g., in a class) that you mention their source (after all, we'd like people to use our book!)
- If you post any slides on a www site, that you note that they are adapted from (or perhaps identical to) our slides, and note our copyright of this material.

Thanks and enjoy! JFK/KWR

Computer Networking: A Top Down Approach
6th edition
Jim Kurose, Keith Ross
Addison-Wesley
March 2012

Chapter 4: outline

4.1 introduction

4.2 ~~virtual circuit and datagram networks~~

4.3 ~~what's inside a router~~

4.4 IP: Internet Protocol
- datagram format
- IPv4 addressing
- ICMP
- IPv6

4.5 routing algorithms
- link state
- distance vector
- hierarchical routing

4.6 routing in the Internet
- RIP
- OSPF
- BGP

4.7 ~~broadcast and multicast routing~~

Network service model

Q: What *service model* for "channel" transporting datagrams from sender to receiver?

A: Below is only a partial list of services that a network layer could provide—there are countless variations possible.

example services for individual datagrams:

- guaranteed delivery
- guaranteed delivery with less than 40 msec delay

The Internet's network layer provides a single service, known as best-effort service.

example services for a flow of datagrams:

- in-order datagram delivery
- guaranteed minimum bandwidth to flow
- restrictions on changes in inter-packet spacing (the amount of time between the transmission of two successive packets at the sender is equal to the amount of time between their receipt at the destination i.e. guaranteed maximum **jitter**)
- Security Services: Encryption

Table 4.1 Internet Service Model

Network Architecture	Service Model	Bandwidth Guarantee	No-Loss Guarantee	Ordering	Timing	Congestion Indication
Internet	Best Effort	None	None	Any order	Not	None

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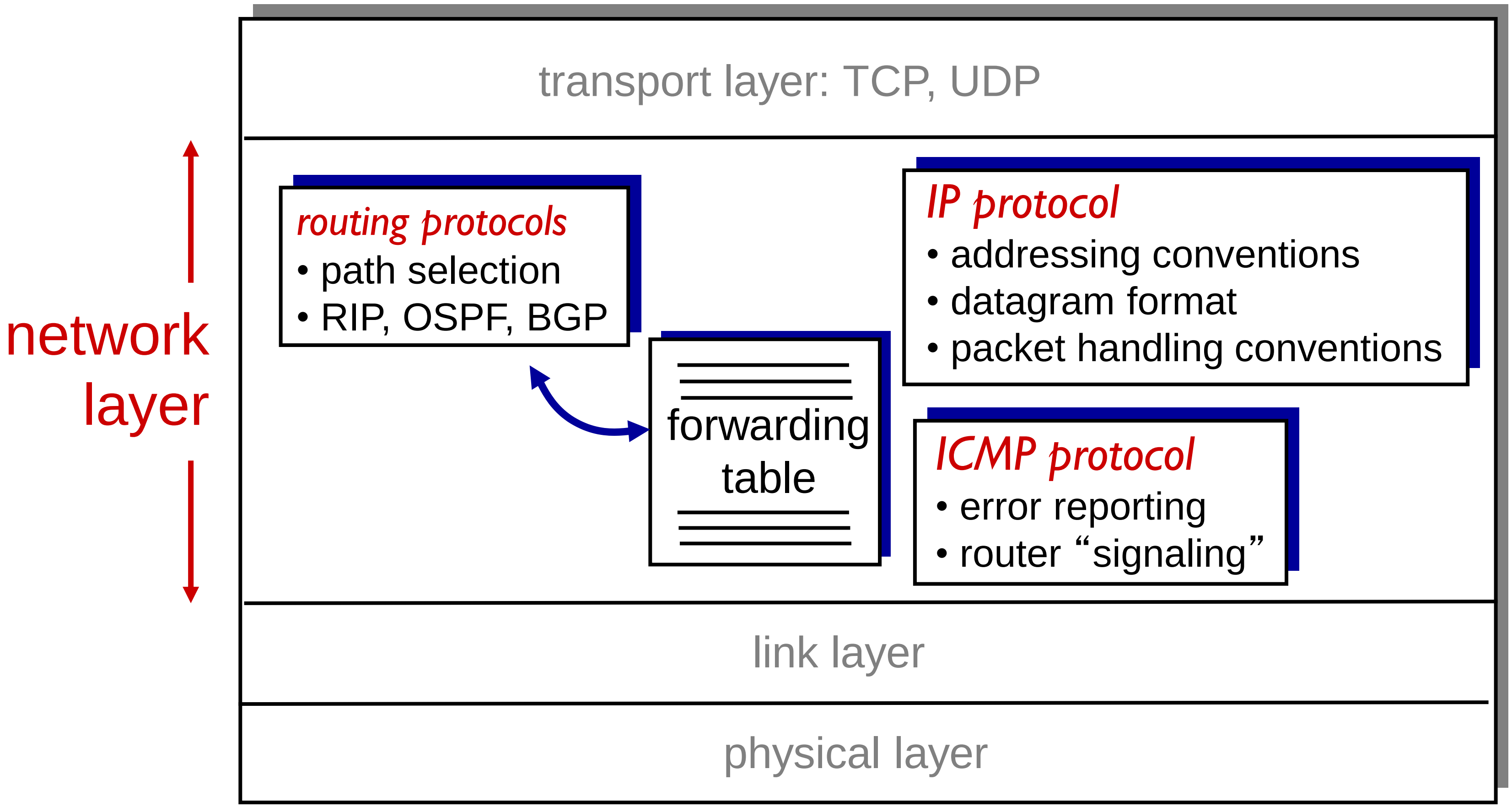
The Internet network layer

host, router network layer functions:



The Internet Network's Layer 3 major components are

1. IP Protocol
2. Routing Component
3. Reporting Errors / Responding to Requests (ICMP, IGMP etc.)

The Internet Protocol (IP)

- *Connectionless* (no call set up at the network layer), *Unreliable designed to be used in a packet switched network like the Internet*
- No *state* about end-to-end connections
- *Best Effort Services* (no bandwidth, loss, error, in order, timing guarantees)
- No *Congestion* indicators

IP relies on TCP for these services

IPv4 datagram format

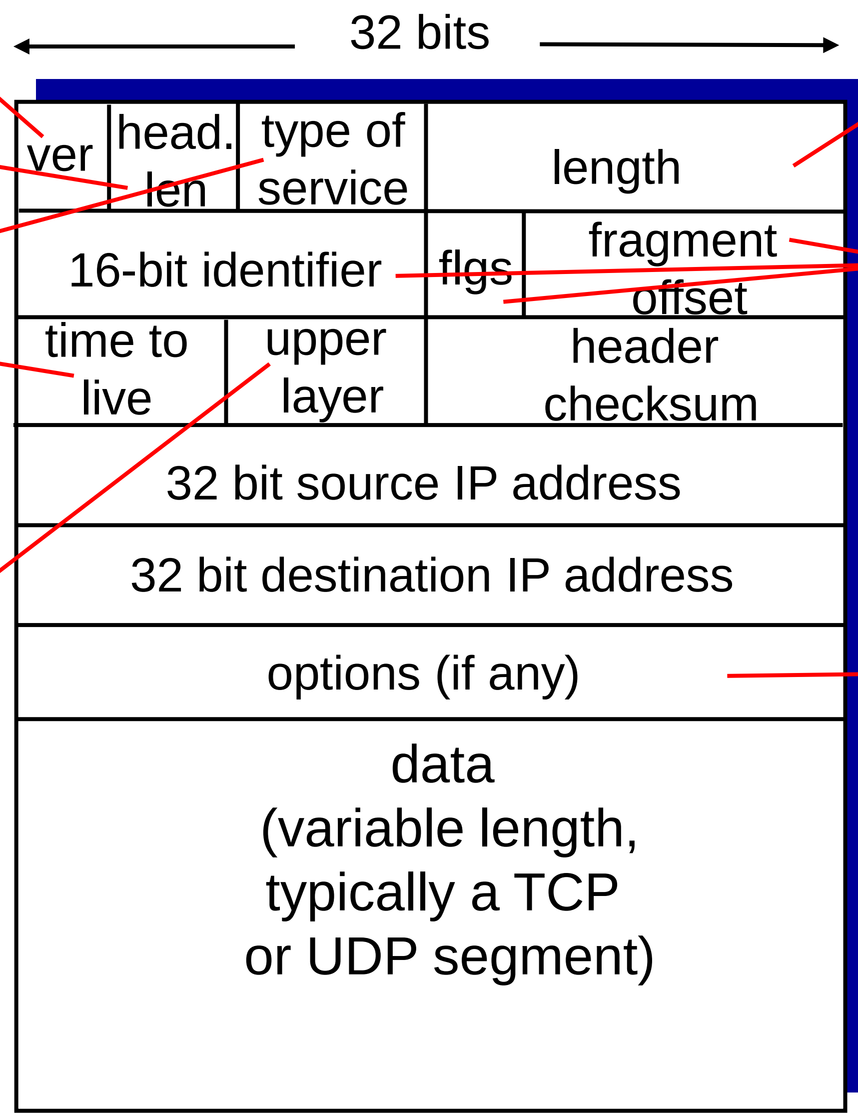
IP protocol version number

header length (bytes)

"type" of data

max number remaining hops (decremented at each router)

upper layer protocol to deliver payload to



total datagram length (bytes)

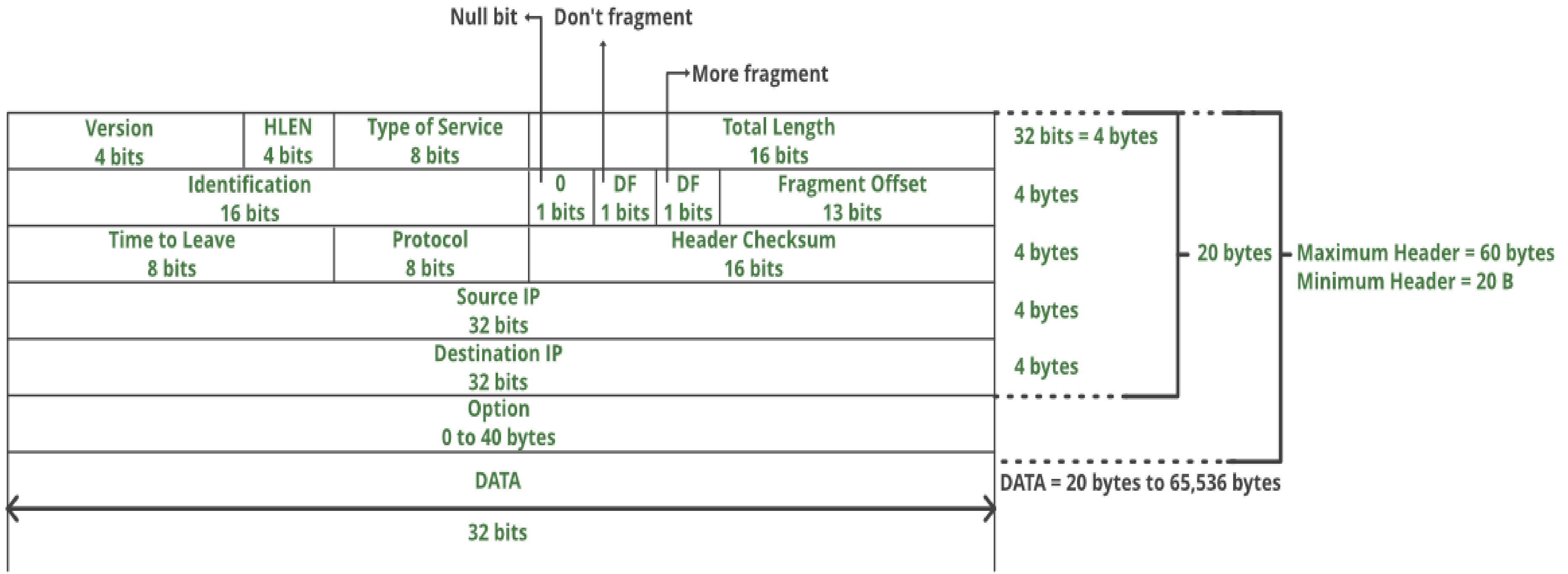
for fragmentation/ reassembly

e.g. timestamp, record route taken, specify list of routers to visit.

how much overhead?

- 20 bytes of TCP
- 20 bytes of IP
- = 40 bytes + app layer overhead
- Typical IP datagram header is 20 bytes (if options not used)

IPv4 Header



- Ver field for IPv4 will always contain the decimal value 4 (i.e. 0100 in binary)
- Header length field is a 4 bit field that contains the length of the IP header in bytes, which always lies in the range of 20 bytes (min) to 60 bytes (max), but the range of these 4 bits can only be from 0000 (i.e. 0 in decimal) to 1111 (i.e. 15 in decimal), so to represent the header length, we use a scaling factor of 4. Thus

Actual Header length = (Header length field value x 4) bytes

IPv4 Header

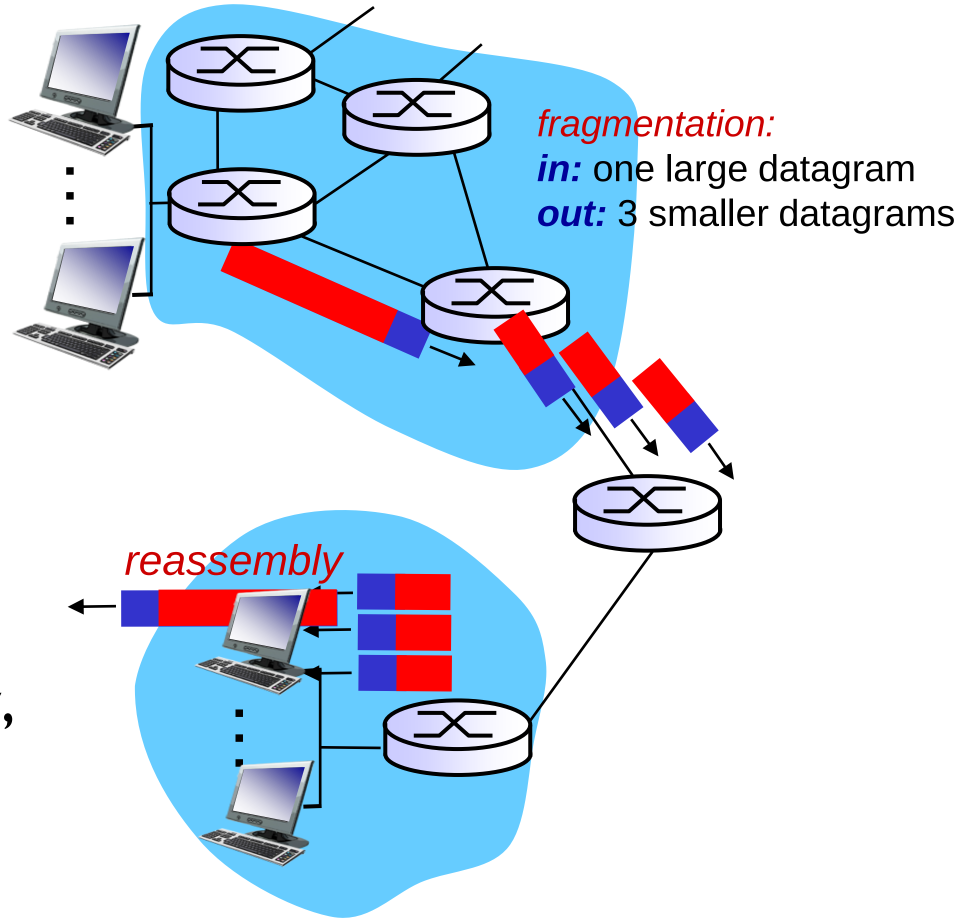
Examples:

- If the header length field contains the value 0101 (i.e. 5 in decimal), then the Actual Header length = 5 x 4 = 20 bytes

- Similarly, if the header length field contains the value 1010 (i.e. 10 in decimal), then the Actual Header length = 10 x 4 = 40 bytes

IPv4 fragmentation, reassembly

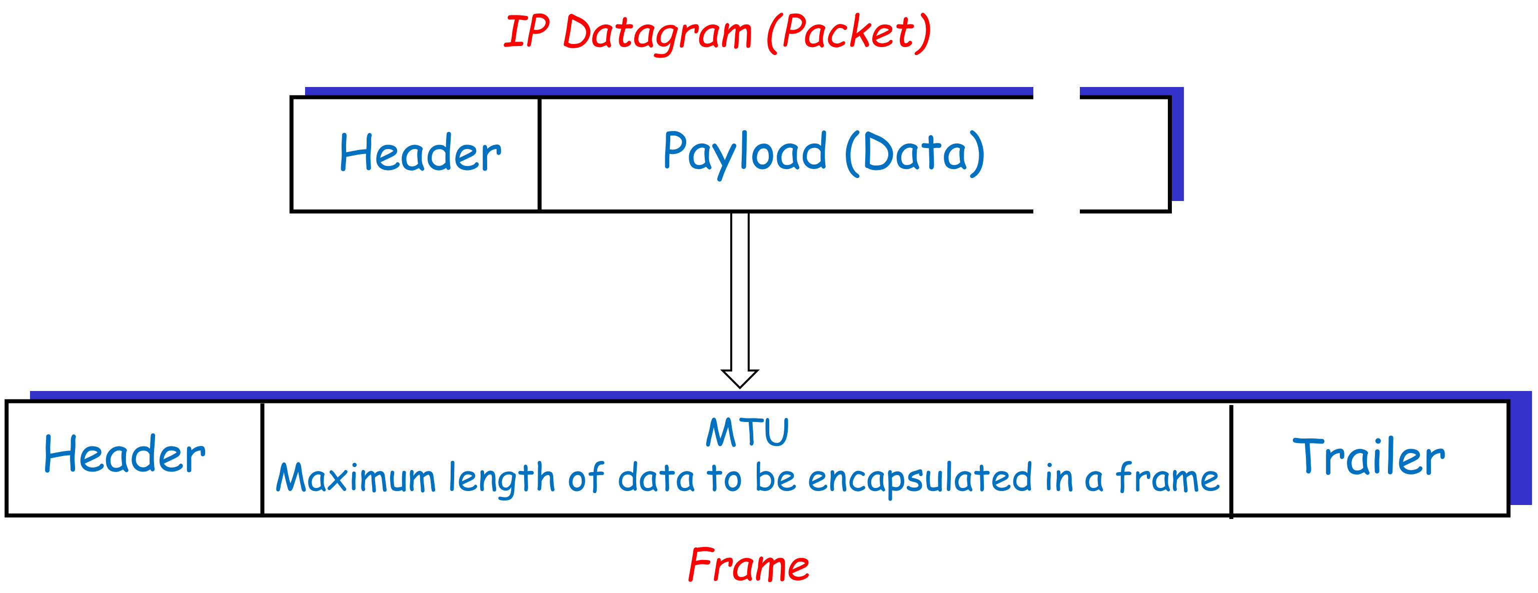
- network links have MTU (max.transfer size) - largest possible link-level frame
  - different link types, different MTUs
- large IP datagram divided ("fragmented") within net
  - one datagram becomes several datagrams
  - IP header bits used to identify, order related fragments
  - The network (i.e. routers) treat fragments as independent units / packets i.e. independent datagrams



IPv4 Fragmentation

- IP packet may travel over different networks (LANs and WANs)
- A router de-capsulate an IP packet from the frame it receives, process it, and encapsulate it in another frame
- Frame size and format varies depend on the data link protocol used by the physical network through which the frame is traveling
- MTU (Maximum Transmission Unit) is the maximum size of the data field (payload) in the frame
- If Packet size > MTU, Need for Fragmentation

Maximum Transmission Unit (MTU)



Protocol	MTU (Bytes)
Ethernet	1500
Token Ring (4 Mbps)	4464
Token Ring (16 Mbps)	17914
FDDI	4352
X.25	576
PPP	296
Wireless	2312

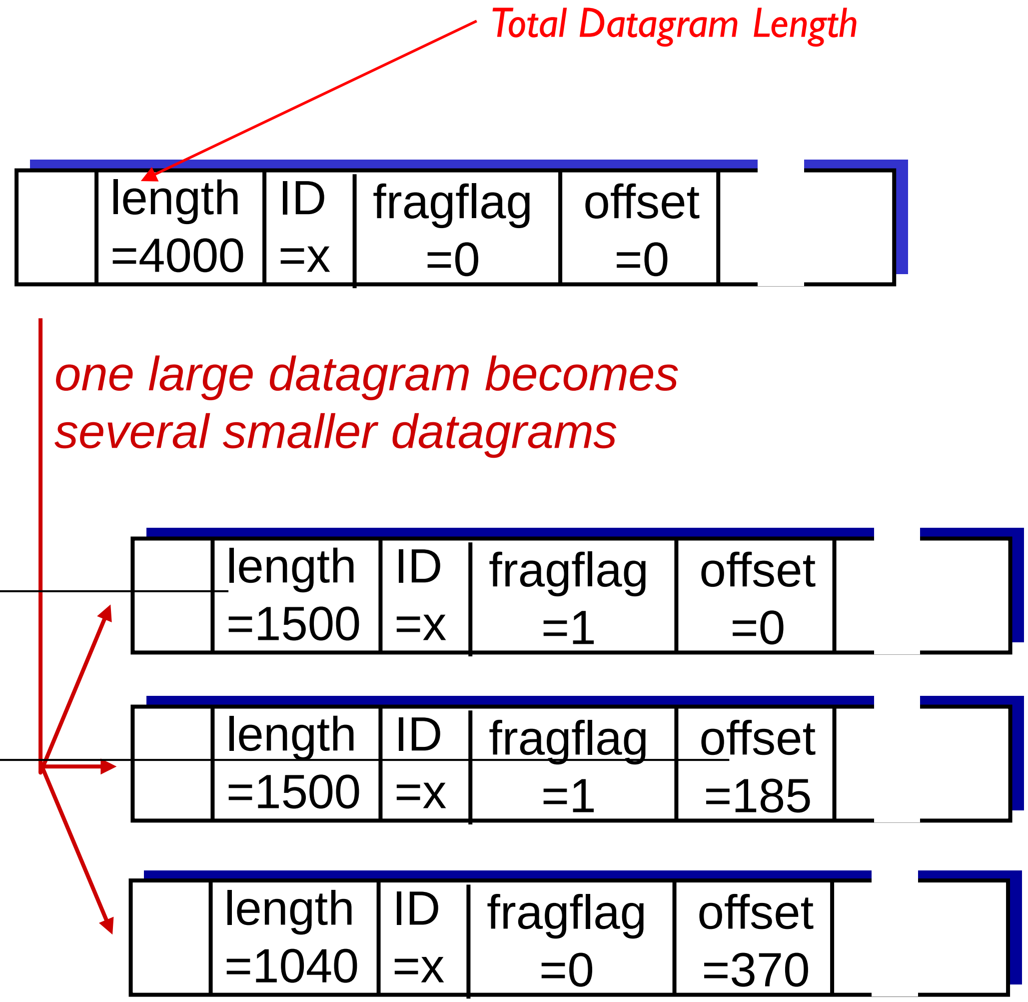
IPv4 Fragmentation (cont'd)

- Each fragment has its own header (most of fields are copied, some will change, including the total length, the Flags and the fragmentation offset fields)
- A fragmented datagram may itself be fragmented if it encounters a network with smaller MTU
- A packet can be fragmented by a source host or by any router in the path. Re-assembly of the packet must be done at the destination host because those fragments become independent packets and may travel different routes

IPv4 fragmentation, reassembly

example:

- 4000 byte datagram (meaning 20 bytes header & 3980 bytes actual payload data)
- MTU = 1500 bytes (meaning 20 bytes header & 1480 bytes actual payload data)
- the payload data of each fragment must be a multiple of 8 bytes of the original payload data in all the fragments (except the last fragment) &
- the offset value be specified in units of 8-byte chunks.



IPv4 Fragmentation (example cont'd)

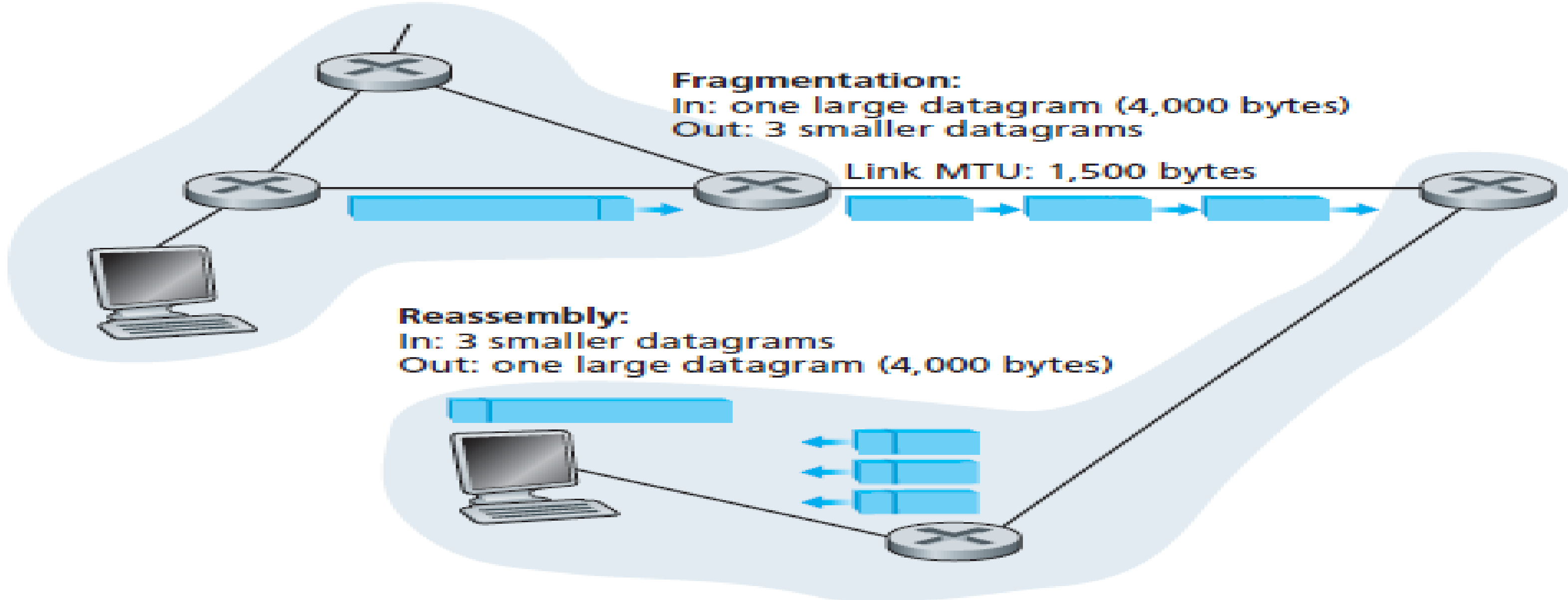


Table 4.2 IP fragments

Fragment	Bytes	ID	Offset	Flag
1st fragment	1,480 bytes in the data field of the IP datagram	identification = 777	offset = 0 (meaning the data should be inserted beginning at byte 0)	flag = 1 (meaning there is more)
2nd fragment	1,480 bytes of data	identification = 777	offset = 185 (meaning the data should be inserted beginning at byte 1,480. Note that 185 · 8 = 1,480)	flag = 1 (meaning there is more)
3rd fragment	1,020 bytes (= 3,980–1,480–1,480 +20) of data	identification = 777	offset = 370 (meaning the data should be inserted beginning at byte 2,960. Note that 370 · 8 = 2,960)	flag = 0 (meaning this is the last fragment)

Quiz # 3 (Chapter – 3)

- ~~***On: Thursday, 20th October, 2022 (During the lecture)***~~

- ***Rescheduled To: Tuesday, 25th October, 2022 (During the lecture)***

- ***Quiz to be taken during own section class only***