CS118 Discussion 1C, Week 6

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Outline

- Network Layer
  - Overview: data v.s. control plane
  - IPv4/IPv6, DHCP
- Midterm review
- Project 2 overview

Network layer: overview

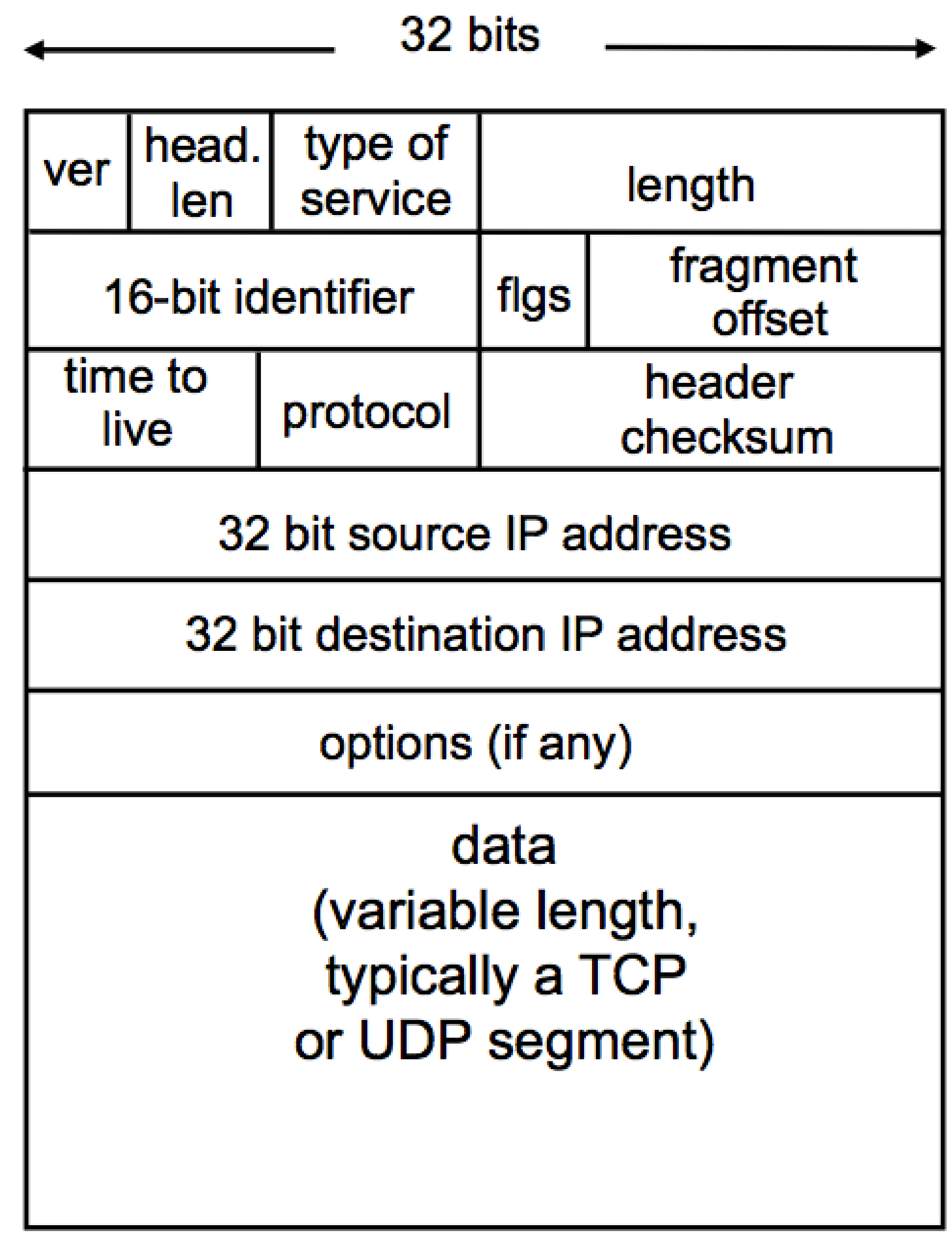
- Basic functions for network layer
  - Forwarding/Routing
- Network service model
  - Guaranteed delivery
  - Guaranteed delivery w/ bounded delay
  - In-order packet delivery
  - Guaranteed minimal bandwidth

Network layer: overview

- Connection v.s. connection-less delivery
  - circuit switch/packet switch
- Network layer protocols
  - Addressing and fragmentation: IPv4, IPv6
  - Routing: RIP, OSPF, BGP, DVMRP, PIM
  - Others: DHCP, ICMP, NAT

IPv4 Header

- **Header length**: 4-byte unit
- **Length**: 1-byte unit
- **Fragmentation**: id + MF/DF + offset (8-byte unit)
- **TTL**: time to live
- **Checksum**
  - Is it redundant?
  - Why is it just checksum for header?
- **Protocol**: identifies the upper layer protocol
- **Source and destination IP addresses**



IP address

- Globally recognizable identifier
- IPv4: 0.0.0.0~255.255.255.255
  - Most IP addresses are globally unique
  - Exception — why?
- Network id, host id
- CIDR address

IP address classes

- http://www.vlsm-calc.net/ipclasses.php

Class	1st Octet Decimal Range	1st Octet High Order Bits	Network/Host ID (N=Network, H=Host)	Default Subnet Mask	Number of Networks	Hosts per Network (Usable Addresses)
A	1 – 126*	0	N.H.H.H	255.0.0.0	126 (2^7 – 2)	16,777,214 (2^{24} – 2)
B	128 – 191	10	N.N.H.H	255.255.0.0	16,382 (2^{14} – 2)	65,534 (2^{16} – 2)
C	192 – 223	110	N.N.N.H	255.255.255.0	2,097,150 (2^{21} – 2)	254 (2^8 – 2)
D	224 – 239	1110	Reserved for Multicasting			
E	240 – 254	1111	Experimental; used for research			

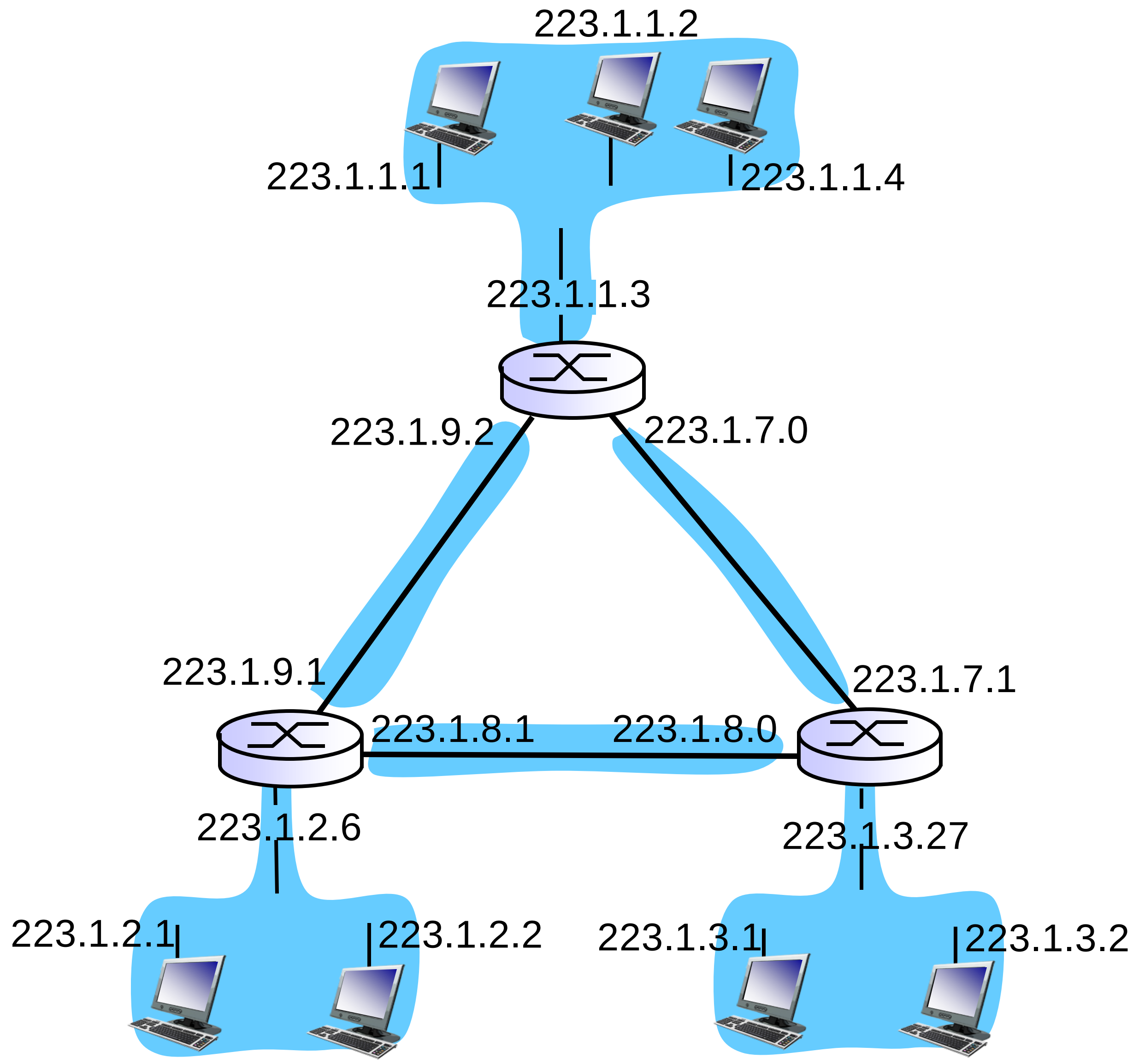
Class	Private Networks	Subnet Mask	Address Range
A	10.0.0.0	255.0.0.0	10.0.0.0 - 10.255.255.255
B	172.16.0.0 - 172.31.0.0	255.240.0.0	172.16.0.0 - 172.31.255.255
C	192.168.0.0	255.255.0.0	192.168.0.0 - 192.168.255.255

Hierarchical addressing

- subnet: a portion of addressing space
    - extend bits from the network id
    - <network address>/<subnet mask>
- route aggregation

Quick question

- How many subnets



CIDR address

- a.b.c.d/x
  - x: # bits in network ID portion of the address
  - address: a.b.c.d, network mask: 2^32 — 2^(32-x)

CIDR 11001000 00010111 00010000 00000000

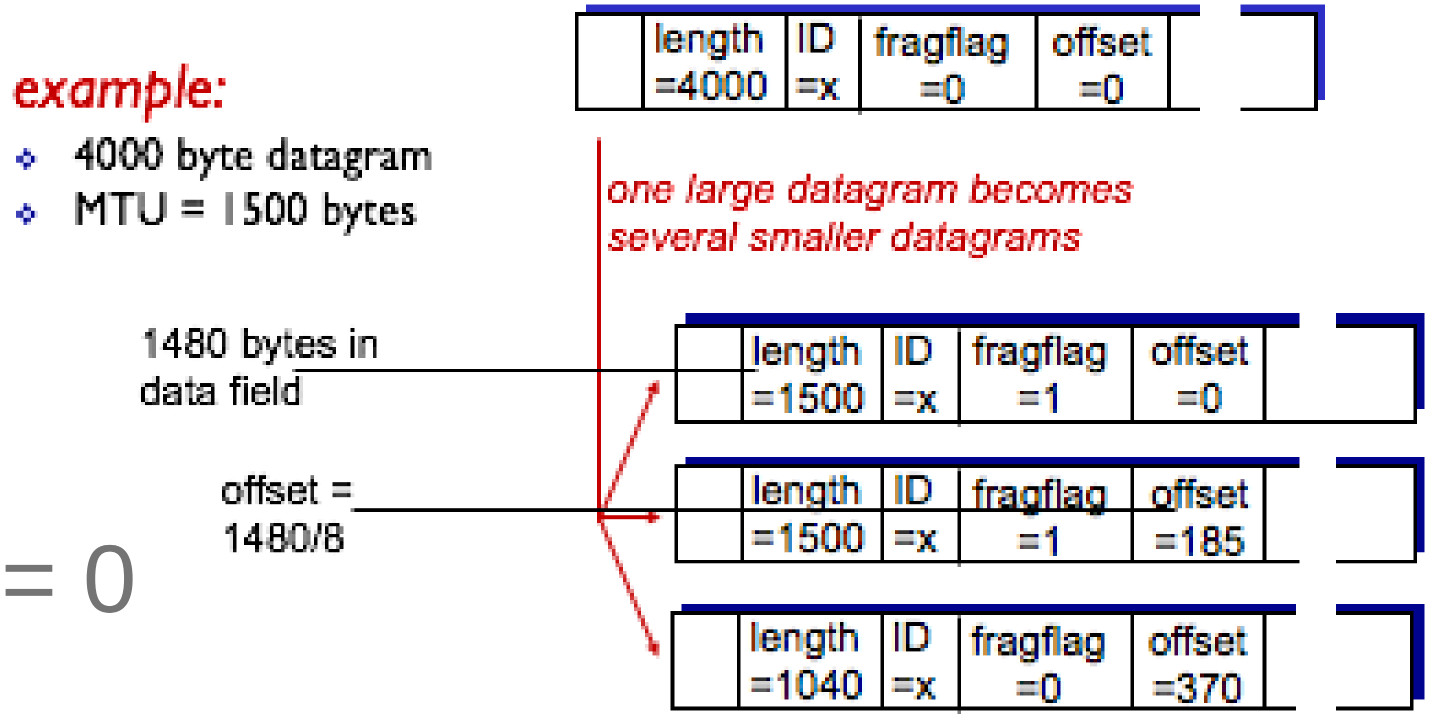
IP prefix 200.23.16.0/23

netmask 11111111 11111111 11111110 00000000

255.255.254.0

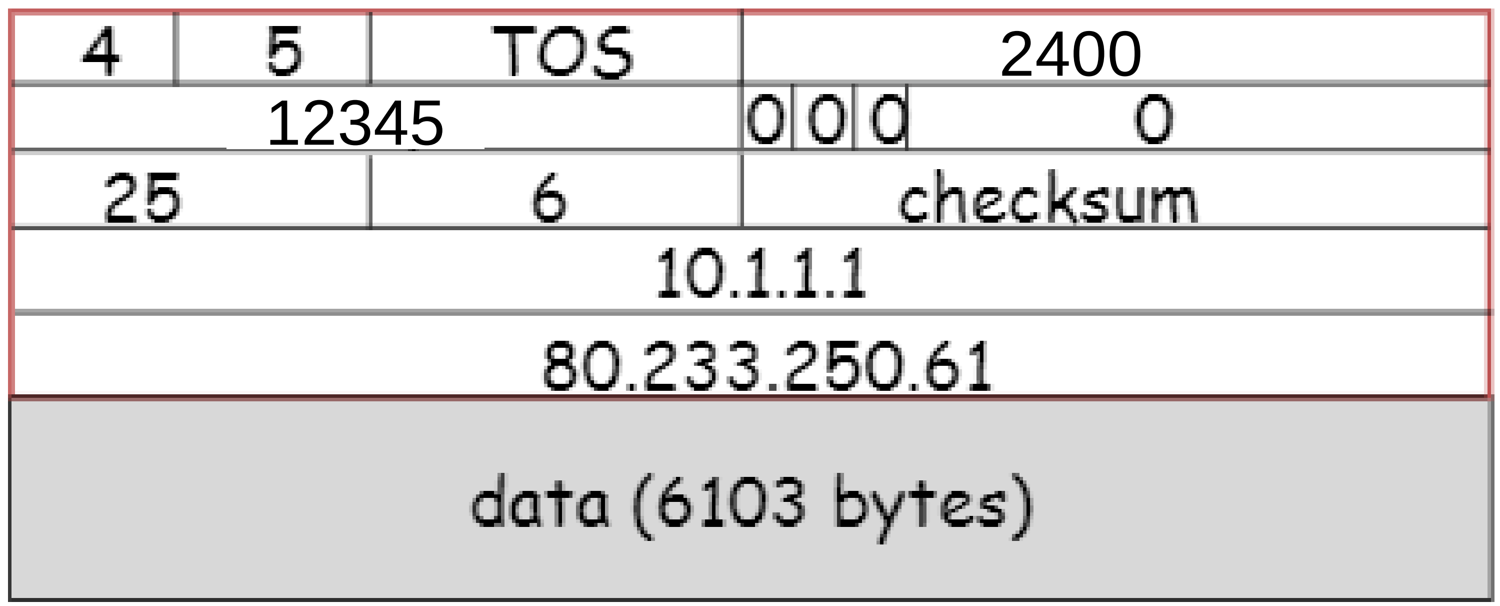
IP fragmentation and reassembly

- MTU: maximum transmission unit
- identifier
- flag bit: three bit
  - DF (Do not Fragment) = 0
  - MF (More Fragments) = 0?
- offset



Quick question

- Consider following IP packet



- Assume MTU = 1450 Bytes. Show the header length, total length, identification, flags, fragment offset, TTL, and IP payload size.

Quick question

- Consider following IP packet

<table>
<tr><td>4</td><td>5</td><td>TOS</td><td colspan="4">2400</td></tr>
<tr><td colspan="3">12345</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td colspan="2">25</td><td>6</td><td colspan="4">checksum</td></tr>
<tr><td colspan="7">10.1.1.1</td></tr>
<tr><td colspan="7">80.233.250.61</td></tr>
</table>

- Assume MTU = 1450 Bytes. Show the header length, total length, identification, flags, fragment offset, TTL, and IP payload size.

For the first packet: 20 bytes, 1444 bytes, ID = 12345, 01, Offset = 0, TTL = 25, 1424 bytes.
For the second packet: 20 bytes, 976 bytes, ID = 12345, 00, Offset = 178, TTL = 25, 956 bytes.

Switching

- Longest prefix matching

Destination Address Range	Link interface
11001000 00010111 00011000 *********	0
11001000 00010111 00010*** *********	1
11001000 00010111 0001**** *********	2
******** ******** ******** ********	3

- Linear lookup

DHCP: Dynamic Host Configuration Protocol

- Dynamically allocates the following info to a host
  - IP address for the host
  - IP address for default router
  - Subnet mask
  - IP address for DNS caching resolver
- Allows address reuse

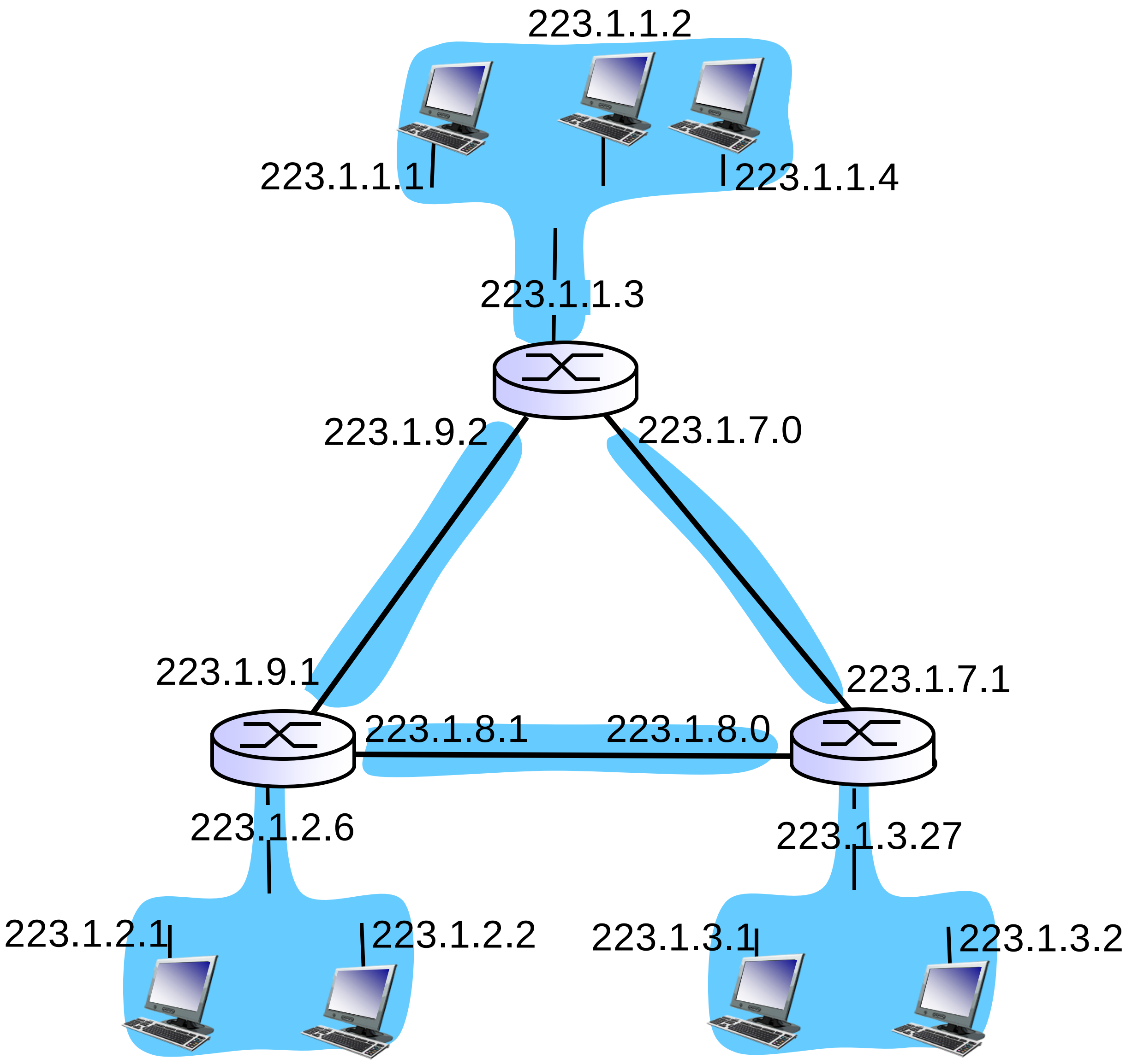
DHCP: operations

- Host broadcasts “DHCP discovery” msg [optional]
- DHCP server responds with “DHCP offer” msg [optional]
- Host requests IP address: “DHCP request” msg
- DHCP server sends address: “DHCP ack” msg

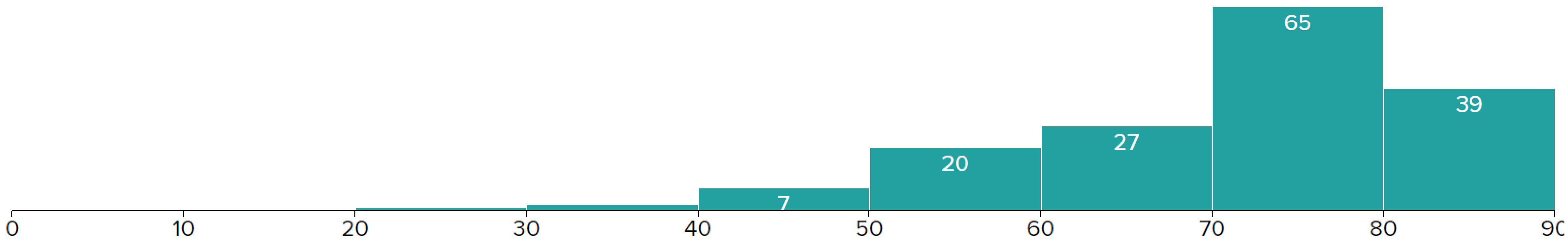
Quick question

- What information in DHCP would change if a host would move from 223.1.1.* to 223.1.1.*?

- What information in DHCP would change if a host would move from 223.1.1.* to 223.1.3.*?



Midterm review



MINIMUM	MEDIAN	MAXIMUM	MEAN	STD DEV
26.0	73.0	88.0	70.81	11.82

Midterm review

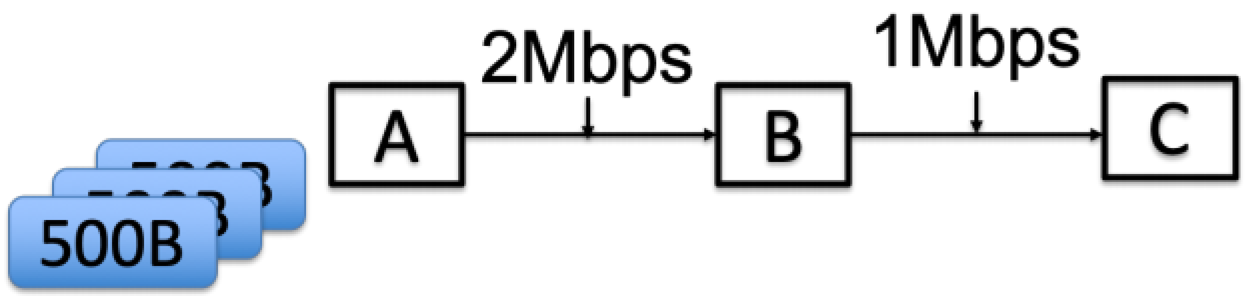
4. AD Which is (are) the potential **drawback(s)** of protocol layering?

   - Your answer ____ (A) One layer may duplicate lower-layer functionality. (B) When a new version of implementation for a layer is released, other layers will not continue to interoperate. (C) Every Internet equipment (e.g., routers and end hosts) has to run every layer of the entire protocol stack. (D) It introduces overhead via the added protocol header at each layer. (E) It achieves the goal of divide and conquer via separation of layers.

9. AD Which statement(s) about Internet process-to-process communication is (are) **correct**?

   - Your answer ____ (A) Internet applications use the process-to-process communication. (B) In P2P mode, there are no client and server processes since all are equal peers. (C) When two mail servers communicate with each other via SMTP, there are no client and server processes since both are servers. (D) One process can communicate with many processes at other hosts. (E) One process can communicate with only one process.

Problem 4 (8 points): Consider sending 3 packets from Node A to Node C via Node B (see the figure below). The packet length is 500 bytes each. The propagation delay of both Link A-B and link B-C is 1 msec (0.001 second). Link A-B's bandwidth is 2Mbps (2×10^6 bits per second), and link B-C's bandwidth is 1Mbps. Assume A starts transmitting the first packet at time t = 0, and no packets are



buffered at B at t = 0.

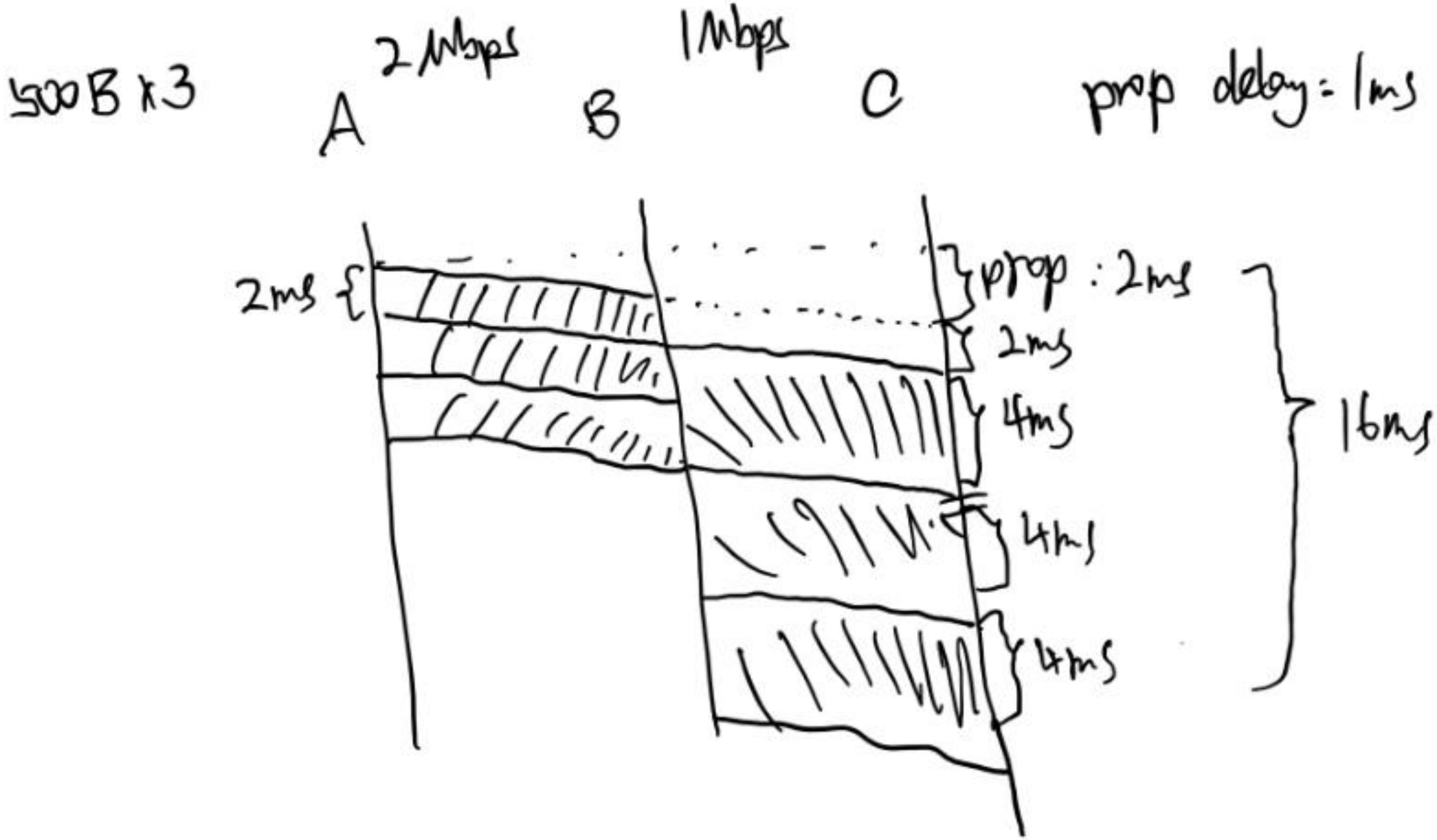
1. (4 points) What is the time gap between the first and second packets when they arrive at C? (i.e., the time gap between receiving the last bit of the first packet and the last bit of the second packet)

   4 point: A $\rightarrow$ B = 500*8/2000000 = 0.002 second
   ?B $\rightarrow$ C = 500*8/1000000 = 0.004 second.
   The first packet arrives at C at t = 8ms = 2ms + 1ms + 4ms + 1ms The second packet starts at t = 2ms. It arrives at B at t = 5ms (2ms + 1ms + 2ms) but it can't be sent out immediately because it needs to wait for the first packet leaving B. It leaves B at t = 7ms and will arrive at C = 12 ms (7ms + 4ms + 1ms).
   So the gap = 4ms.
   (A simpler answer is the bottleneck link is B-C. The second packet can be sent at B after the first packet leaves B. The gap is 4ms (B $\rightarrow$ C = 500*8/1000000 = 0.004 second).

2. (4 points) When will C receive all 3 packets?

   0.008 + 0.004*2 = 0.016 (16ms)

4.2



500B x 3
2 Mbps
1 Mbps
A
B
C
prop delay = 1ms
2ms
prop : 2ms
2ms
4ms
4ms
4ms
16ms

Project 2 overview

The best way to approach this project is in incremental steps. Do not try to implement all of the functionality at once.

- First, assume there is no packet loss, implement the header fields and connection control functions (initialization with 3-way handshake and termination). Just have the client initiate the connection with 3-way handshake, send a small file (200 Bytes) as a packet, and the server respond with an ACK, and then the server use FIN procedure to close the connection.
- Second, introduce a large file transmission and pipe-lining. This means you must divide the file into multiple packets and transmit the packets based on the specified window size.
- Third, introduce packet loss. Now you have to add a timer for last sent packet (Go-Back-N) or several timers for each unacked packets (Selective repeat). If a timer times out, the corresponding (lost) packet should be retransmitted for the successful file transmission.

Stage 0：Small file transmission

- Small file transmission
  - A client initiate file transmission
  - A server accept connection requests, receive the file and save it with x.file
    - X indicated the counter of connection (starts with 1)
- Test
  - ./server 5000
  - ./client localhost 5000 testfile
  - In the server folder, check whether 1.file is saved and compare two files with diff command.

Stage 1: connection management

- Connection management

```
      Client1                                     Server
  (A 500-byte file to send)
         |                                          |
Random #     seq=12345, ack=0, SYN                  |
         |  -------------------------------------> |
         |    seq=221, ack=12346, SYN, ACK          |
         | <-------------------------------------  |
         |                                          |
         |        seq=12346, ack=222, ACK           |
         |  -------------------------------------> |
         |     (if include 500-byte payload)        |
         |        seq=222, ack=12846, ACK           |
         | <-------------------------------------  |
         |                                          |
         |                                          |
         |   FIN procedures to close connection     |
         | <-------------------------------------> |
         |         (saves file 1.file)              |
         |                                          |
       close                                        |
     connection                                     |
```

```
               Client                                       Server
      (A 10000-byte file to send)
                  |                                           |
                 ...                                         ...
                  |        (10000 bytes transferred)          |
                  |                                           |
                  |       seq=22346, ack=0, FIN               |
                  | ---------------------------------------> |
                  |          (no payload in FIN)              |
                  |                                           |
                  |       seq=4322, ack=22347, ACK            |
                  | <---------------------------------------  |
                  |                                           |
                  |                                           |
                  |       seq=4322, ack=0, FIN                |
          +-->    | <---------------------------------------  |
      2   |       |       seq=22347, ack=4323, ACK            |
      s   |       | ---------------------------------------> |
      e   |       |                                           |
      c   |      ...          (if ACK is lost)               ...
      o   |       |                                           |
      n   |       |       seq=4322, ack=0, FIN                |
      d   |       | <---------------------------------------  |
      s   |       |       seq=22347, ack=4323, ACK            |
          |       | ---------------------------------------> |
      w   |       |                                           |
      a   |      ...                                        close
      i   |       |                                      connection
      t   |       |
          |       |
          +-->    |
                close
              connection
```

Stage 1: connection management

- Packet header struct (12 bytes)
  - Needed fields: a Sequence Number field, an Acknowledgment Number field, and ACK, SYN , and FIN flags.
  - Example：
    - uint16_t to represent each field.
    - In total, 5*2 bytes are used. Then pad 2 byte of zeros.
  - Functions: printPacket(), htonHeader(), ntohHeader().

Stage 1: connection management

- Packet header struct (12 bytes)
- Example to construct a SYN packet
  - Header h1, then memset the struct
  - Set sequence number fields of h1 with a random number
  - Set SYN flag
  - Print header “SEND 12345 0 SYN”
- Example to parse a packet
  - Print header “RECV 4321 12346 SYN ACK”

Stage 1: connection management

- Client side logic
  - Send a packet with SYN to initiate the connection.
  - After receive packet with ACK, start send packets with data.
  - After transmitting the entire file, send FIN packet and wait for ACK.
  - After receive server FIN, send ACK and wait for 2 seconds to close the connection.

Note: always need to print out the header

Stage 1: connection management

- Server side logic
  - If a SYN packet, reply with packet with SYN flag and ACK flag, set ACK number field and sequence number field
  - If a data packet, write data field to file
  - If a FIN packet, reply with packet with ACK flag. Then send a packet with FIN flag. After receive ACK from client, close the connection.

Note: always need to print out the header

Stage 2: large file transmission and pipelining

- Pipelining
  - For client side, send 10 packets at the same time.
    - For every received ACK, send a new packet out. Keep the window at 10.
  - For server side, no much difference
- Large file transmission
  - Pay attention to sequence number (max = 23600)

Stage 3: reliable data transfer with packet loss

- Go-back-N is recommended
- For client side
  - Keep a timer, restart the timer for every sent packet.
  - If timeout, resend all packets in the window.
- For server side
  - Keep expected sequence number
  - Every time a data packet is received, check whether the sequence number is expected. If expected, write data field, otherwise drop it.