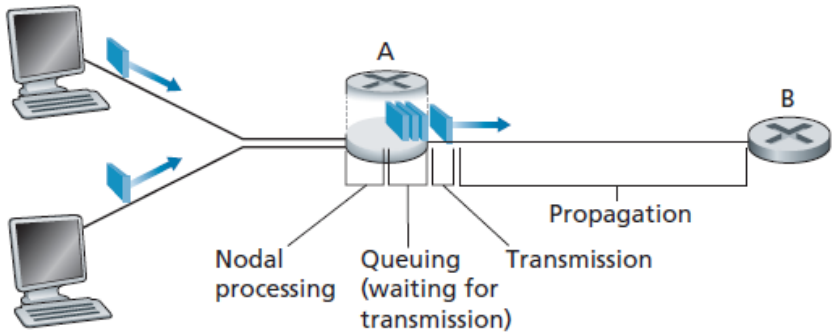
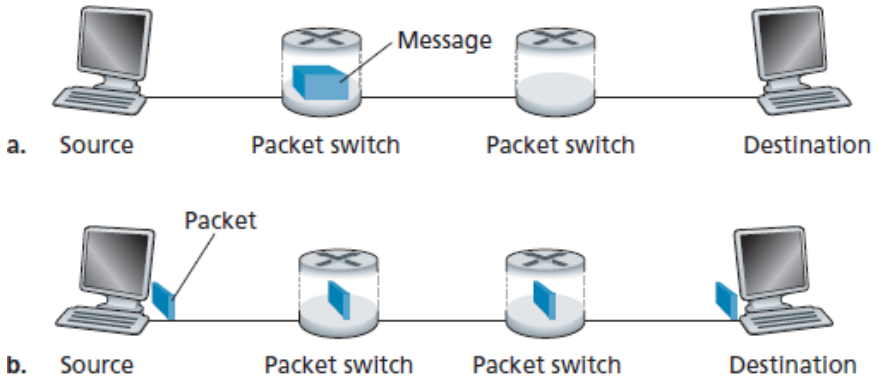
1. What are the different layers of the TCP/IP model? State the purpose of each layer.
2. What are the various types of ISPs? Briefly explain the different ways by which the various ISPs can interconnect to form the network core. Depict the resulting interconnection model.
3. Classify the network edge based on the usage and ownership. Classify the physical media used in the network edge.
4. State the key differences between the circuit switching and packet switching.
5. Consider the network illustrated below. Assume the two hosts on the left of the figure start transmitting packets of 1500 bytes at the same time towards Router B. Suppose the link rates between the hosts and Router A is 4-Mbps. One link has a 6-ms propagation delay and the other has a 2-ms propagation delay. Will queuing delay occur at Router A?



6. What is traffic intensity? Explain the impact of traffic intensity on queuing delay. What is the impact of queuing delay on throughput?
7. Consider a message that is 10 Mb long that is to be sent from source to destination as given in the figure below. Suppose each link in the figure is 5 Mbps. Ignore propagation, queuing, and processing delays. Answer the following questions.



End-to-end message transport: (a) without message segmentation; (b) with message segmentation

   a. Consider sending the message from source to destination *without* message segmentation. How long does it take to move the message from the source host to the first packet switch? Keeping in mind that each switch uses store-and-forward packet switching, what is the total time to move the message from source host to destination host?
   b. Now suppose that the message is segmented into 100 packets, with each packet being 10,000 bits long. How long does it take to move the first packet from source host to the first switch? When the first packet is being sent from

the first switch to the second switch, the second packet is being sent from the source host to the first switch. At what time will the second packet be fully received at the first switch?

c. How long does it take to move the file from source host to destination host when message segmentation is used? Compare this result with your answer in part (a) and comment.

8. Consider the following string of ASCII characters that were captured by Wireshark when the browser sent an HTTP GET message (i.e., this is the actual content of an HTTP GET message). The characters <*cr*><*lf*> are carriage return and line-feed characters (that is, the italicized character string <*cr*> in the text below represents the single carriage-return character that was contained at that point in the HTTP header). Answer the following questions, indicating where in the HTTP GET message below you find the answer.

```
GET /cs453/index.html HTTP/1.1<cr><lf>Host: gai
a.cs.umass.edu<cr><lf>User-Agent: Mozilla/5.0 (
Windows;U; Windows NT 5.1; en-US; rv:1.7.2) Gec
ko/20040804 Netscape/7.2 (ax) <cr><lf>Accept:ex
t/xml, application/xml, application/xhtml+xml, text
/html;q=0.9, text/plain;q=0.8,image/png,*/*;q=0.5
<cr><lf>Accept-Language: en-us,en;q=0.5<cr><lf>Accept-
Encoding: zip,deflate<cr><lf>Accept-Charset: ISO
-8859-1,utf-8;q=0.7,*;q=0.7<cr><lf>Keep-Alive: 300<cr>
<lf>Connection:keep-alive<cr><lf><cr><lf>
```

a. What is the URL of the document requested by the browser?
b. What version of HTTP is the browser running?
c. Does the browser request a non-persistent or a persistent connection?
d. What is the IP address of the host on which the browser is running?
e. Will this HTTP message generate a HTTP reply with the status code and phase 304 and Not Modified respectively?

9. The text below shows the reply sent from the server in response to the HTTP GET message in the question above. Answer the following questions, indicating where in the message below you find the answer.

a. Was the server able to successfully find the document or not? What time was the document reply provided?
b. When the document was last modified?
c. How many bytes are there in the document being returned?
d. What are the first 5 bytes of the document being returned? Did the server agree to a persistent connection?

```
HTTP/1.1 200 OK<cr><lf>Date: Tue, 07 Mar 2008
12:39:45GMT<cr><lf>Server: Apache/2.0.52 (Fedora)
<cr><lf>Last-Modified: Sat, 10 Dec2005 18:27:46
GMT<cr><lf>ETag: "526c3-f22-a88a4c80"<cr><lf>Accept-
Ranges: bytes<cr><lf>Content-Length: 3874<cr><lf>
Keep-Alive: timeout=max=100<cr><lf>Connection:
Keep-Alive<cr><lf>Content-Type: text/html; charset=
ISO-8859-1<cr><lf><cr><lf><!doctype html public "-
//w3c//dtd html 4.0transitional//en"><lf><html><lf>
<head><lf> <meta http-equiv="Content-Type"
content="text/html; charset=iso-8859-1"><lf> <meta
name="GENERATOR" content="Mozilla/4.79 [en] (Windows NT
5.0; U) Netscape]"><lf> <title>CMPSCI 453 / 591 /
NTU-ST550ASpring 2005 homepage</title><lf></head><lf>
<much more document text following here (not shown)>
```

10. Consider the figure given below, for which there is an institutional network connected to the Internet. Moreover, assume the access link has been upgraded to 54 Mbps, and the institutional LAN is upgraded to 10 Gbps. Suppose that the average object size is 1,600,000 bits and that the average request rate from the institution's browsers to the origin servers is 24 requests per second. Also suppose that the amount of time it takes from when the router on the Internet side of the access link forwards an HTTP request until it receives the response is three seconds on average. Model the total average response time as the sum of the average access delay (i.e., the delay from Internet router to institution router) and the average Internet delay. For the average access delay, use $\Delta/(1-\Delta\beta)$, where Δ is the average time required to send an object over the access link and β is the arrival rate of objects to the access link.
    a. Find the total average response time.
    b. Now suppose a cache is installed in the institutional LAN. Suppose the miss rate is 0.3. Find the total response time.
11. What are the different types of server placement under CDN? Briefly explain the approaches. Briefly explain the role of DNS in retrieving the IP address of CDN server which hosts the video belonging to the content provider (e.g., video.netcinema.com/6Y7B23V).
12. Explain the role of the client and the content server under the context of streaming a video over DASH. Which application protocol is invoked by the client prior to the commencement of the video streaming?
13. Explain the delivery of an email message from the sender's mail server to the recipient's mail server. Assume the emails of the sender and recipient as alice@crepes.fr and bob@hamburger.edu.
14. What are the various fields contained in a DNS resource record? Provide the significance of these fields.
15. What are the different DNS servers? Why do we need a local DNS server? Briefly explain the role of the DNS in the internet.
16. Explain the purpose of web caching with a neat illustration. What are the pros and cons of web-caching?
17. A packet switch receives a packet and determines the outbound link to which the packet should be forwarded. When the packet arrives, one other packet is halfway done being transmitted on this outbound link and four other packets are waiting to be transmitted. Packets are transmitted in order of arrival. Suppose all packets are 1,500 bytes and the link rate is 2 Mbps. What is the queuing delay for the packet? More generally, what is the queuing delay when all packets have length L, the transmission

rate is R, x bits of the currently-being-transmitted packet have been transmitted, and n packets are already in the queue?

18. Consider the case where end hosts A and B are connected by a one hop router and the links have the same transmission rate R (Mbps). Assume that the host A has P packets of variable length $\{L_1...,L_P\}$ bits to transmit to host B. Assume that the processing delays and propagation delays are negligible.
    a. Calculate the end-end delay in transmitting P packets. Explain your calculation.
    b. Calculate the end-end delay in transmitting P packets via M routers between A and B. All links have the same transmission rate R. Explain your calculation.
19. Suppose N packets arrive simultaneously to a link at which no packets are currently being transmitted or queued. Each packet is of length L and the link has transmission rate R. What is the average queuing delay for the N packets?
20. Draw a simple timing diagram indicating the delays involved in retrieving a web page containing the base HTML object and 4 additional images using
    a. Persistent HTTP
    b. Non-persistent HTTP and
    c. Persistent HTTP with three parallel connections. Assume size of all objects to be negligible. Express total delay in terms of RTT.