P12. 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 2.5 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?

L (packet length) = 1500 bytes
R (transmission rate) = 2.5 Mbps
x (currently transmitting packet) = L / 2 = 750 bytes
n (number in queue) = 4 packets
Queuing Delay = (nL + (L – x)) / R
= (4 * 1500 + (1500 – 750)) bytes / 2.5 Mbps
= 6570 bytes / 2.5 Mbps
= 0.050125 Mb / 2.5 Mbps
= 0.02005 seconds

P13. (a) 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?
(b) Now suppose that N such packets arrive to the link every LN/R seconds. What is the average queuing delay of a packet?

a) Queuing delay for first packet: 0
Queuing delay for second: L/R
Queuing delay generally: (N-1)L / R
Average delay: (N-1)L / 2R
b) It takes LN/R seconds to transmit N packets, the queue is empty each time a new batch arrives, so the average delay across all batches is: (N-1)L / 2R

P18. Perform a Traceroute between source and destination on the same continent at three different hours of the day.
a. Find the average and standard deviation of the round-trip delays at each of the three hours.
b. Find the number of routers in the path at each of the three hours. Did the paths change during any of the hours?
c. Try to identify the number of ISP networks that the Traceroute packets pass through from source to destination. Routers with similar names and/ or similar IP addresses should be considered as part of the same ISP. In your experiments, do the largest delays occur at the peering interfaces between adjacent ISPs?

d. Repeat the above for a source and destination on different continents. Compare the intra-continent and inter-continent results.

Delays at Traceroute between my home and google.com respectively: 6 ms, 8ms, 10 ms
a) average = 8 ms
standard deviation = 1.63299316186 ms
b) 11 routers; did not change
c) Yes, in this experiment the largest delays occurred at peering interfaces between adjacent ISPs.
d) The intra-continent results are used to makes faster to reach to the DNS than inter- continent.

P24. Suppose you would like to urgently deliver 50 terabytes data from Boston to Los Angeles. You have available a 100 Mbps dedicated link for data transfer. Would you prefer to transmit the data via this link or instead use FedEx overnight delivery? Explain.

50 terabytes = 50 * 10^12 * 8 bits
Time by link = 50 * 10^12 * 8 / 100 * 10^6= 4000000 seconds ≈ 46.3 days
Whereas FedEx overnight delivery only takes one day, so I prefer to transmit the data via FedEx overnight delivery.

P26. Referring to problem P24(P25), suppose we can modify R. For what value of R is the width of a bit as long as the length of the link?

R = s/m = 2.5 * 10^8 / 2 * 10^7 = 12.5bps

P31. In modern packet-switched networks, including the Internet, the source host segments long, application-layer messages (for example, an image or a music file) into smaller packets and sends the packets into the network. The receiver then reassembles the packets back into the original message. We refer to this process as message segmentation. Figure 1.27 illustrates the end-to-end transport of a message with and without message segmentation. Consider a message that is 10^6 bits long that is to be sent from source to destination in Figure 1.27. Suppose each link in the figure is 5 Mbps. Ignore propagation, queuing, and processing delays.

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?**

Time = 10^6 / 5 *10^6 = 0.2 sec
Total time = 0.2 sec * 3 hops = 0.6 sec

P32. Experiment with the Message Segmentation interactive animation at the book's Web site. Do the delays in the interactive animation correspond to the delays in the previous problem? How do

link propagation delays affect the overall end-to-end delay for packet switching (with message segmentation) and for message switching?

Yes, the delays in the applet correspond to the delays in the previous problem.
Propagation delay also has the same effect on the overall end-to-end delay of both packet switching and message switching.

P33. Consider sending a large file of F bits from Host A to Host B. There are three links (and two switches) between A and B, and the links are uncongested (that is, no queuing delays). Host A segments the file into segments of S bits each and adds 80 bits of header to each segment, forming packets of L = 80 + S bits. Each link has a transmission rate of R bps. Find the value of S that minimizes the delay of moving the file from Host A to Host B. Disregard propagation delay.

Time at first packet received = $(80 + S)/R * 3$ sec
Time for after packet received = $(80 + S)/R$ sec
Time for whole file received = $(80 + S)/R * 3 + (80 + S)/R * (F/S - 1)$
$= (80 + S)/R * (F/S + 2) = T$
$dT/dS = 0$
$S = \sqrt{(40F)}$