Chapter 1
Examples and Homework Problems

Example 1

How long does it take a packet of length 1000 bytes to propagate over a link of distance 2500km, propagation speed2.5×10^8 m/s, and transmission rate 2 Mbps?

(1) More generally, how long does it take a packet of length L to propagate over a link of distance d, propagation speed s, and transmission rate R bps?

(2) Dose this delay depend on packet length?

(3) Does this delay depend on transmission rate?

Solution to Example 1

(1) How long does it take a packet of length 1000 bytes to propagate over a link of distance 2500km, propagation speed 2.5×10^8 m/s, and transmission rate 2 Mbps?

Ans: (2500*10^3)/(2.5*10^8)=0.01s = 10ms

(2) More generally, how long does it take a packet of length *L* to propagate over a link of distance *d*, propagation speed *s*, and transmission rate *R* bps?

Ans: d/s

(3) Dose this delay depend on packet length? No

(4) Does this delay depend on transmission rate? No

Example 2

Suppose Host A wants to send a large file to Host B.The path from Host A to Host B has three links, of rate $R1$=500kbps, $R2$=2Mbps, and $R3$=1Mbps.

a. Assuming no other traffic in the network, what is the throughput for the file transfer?
b. Suppose the file is 4 million bytes. Dividing the file size by the throughput, roughly how long will it take to transfer the file to Host B?
c. Repeat (a) and (b), but now with $R2$ reduce to 100kpbs.

Solution to Example 2

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a. Assuming no other traffic in the network, what is the throughput for the file transfer?

Ans: 500kpbs.

a. Suppose the file is 4 million bytes. Dividing the file size by the throughput, roughly how long will it take to transfer the file to Host B?

Ans: (4*10^6)*8/(500*10^3)= 64 seconds

a. Repeat (a) and (b), but now with $R2$ reduce to 100kpbs.

Ans: 100kbps, 4*10^6*8/100*10^3= 320 seconds

Example 3

Visit the Queuing and Loss applet at the companion web site. What is the maximum emission rate and the minimum transmission rate? With those rates, what is the traffic intensity?

Run the applet with these rates and determine how long it takes for packet loss to occur. Then repeat the experiment a second time and determine again how long it takes for packet loss to occur. Are the values different?

Packet Loss 1st Run

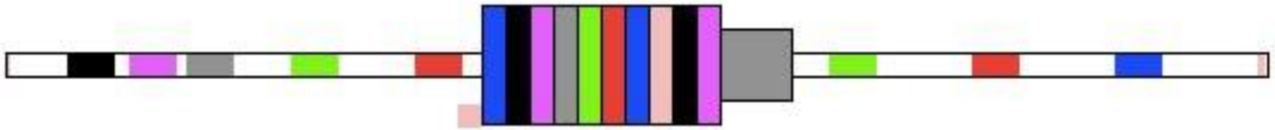
Queuing and Loss Applet

Queuing and Loss Applet

As we learned in Chapter 1, the most complicated and interesting component of end-to-end delay is queuing delay. In this applet, you specify the packet arrival rate and the link transmission speed. You'll then see packets arrive and queue for service. When the queue becomes full, you'll see the queue overflow--that is, packet loss.

A particularly interesting case is when the emission and transmission rates are the same, for example when both are 500 packets/sec. If you let the applet run for a very long time, you'll eventually see the queue fill up and overflow. Indeed when the two rates are the same (that is, ρ = 1), the queue grows without bound (with random inter-arrival times), as described in the text.

Emission rate 500 packet/s Transmission rate 350 packet/s Start Reset



64 msec
1 packets dropped out of 29

View the source code

This applet was designed and coded by David Grangier as part of course work at Eurecom Institute.

Packet Loss 2nd Run

Queuing and Loss Applet

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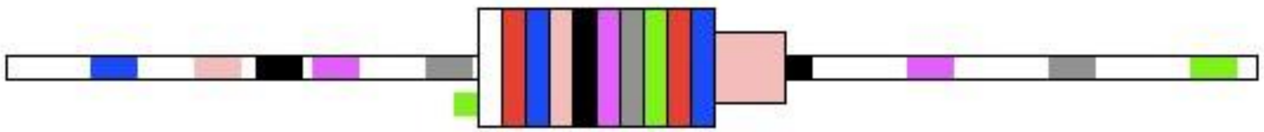


93 msec
1 packets dropped out of 38

View the source code

This applet was designed and coded by David Grangier as part of course work at Eurecom Institute.

Solution to Example 3

Visit the Queuing and Loss applet at the companion web site.What is the maximum emission rate and the minimum transmission rate? With those rates, what is the traffic intensity?

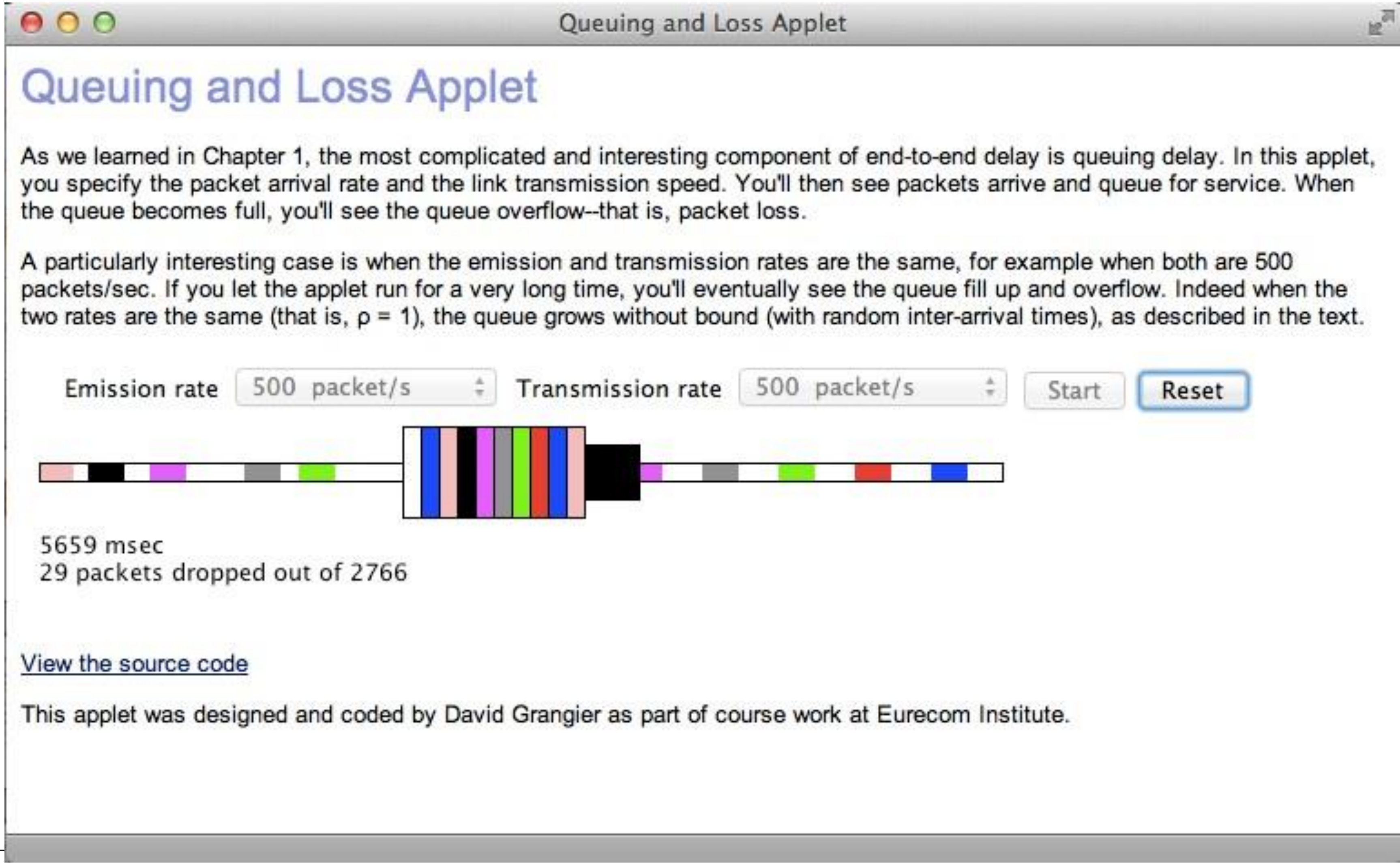
Run the applet with these rates and determine how long it takes for packet loss to occur.Then repeat the experiment a second time and determine again how long it takes for packet loss to occur. Are the values different?

Ans: The maximum emission rate is 500 packets/sec and the maximum transmission rate is 350 packets/sec.

The corresponding traffic intensity is 500/350 =1.43 > 1. Loss will eventually occur for each experiment; but the time when loss first occurs will be different from one experiment to the next due to the randomness in the emission process.

Packet Loss under TI=1

- When the emission and transmission rate are the same,TI=1, the queue grows without bound (with random inter-arrival times)



Example 4

The end-to-end delay of sending a packet consisting L bits from source to destination over a path consisting N links each of rate R is (NL/R). Generalize this formula for sending P such packets back-to-back over the N links.

Solution to Example 4

The end-to-end delay of sending a packet consisting L bits from source to destination over a path consisting N links each of rate R is (NL/R). Generalize this formula for sending P such packets back-to-back over the N links.

Ans:

At time N*(L/R) the first packet has reached the destination, the second packet is stored in the last router, the third packet is stored in the next-to-last router, etc. At time N*(L/R) + L/R, the second packet has reached the destination, the third packet is stored in the last router, etc. Continuing with this logic, we see that at time N*(L/R) + (P-1)*(L/R) = (N+P-1)*(L/R) all packets have reached the destination.

Homework Problems for Chapter 1

Problem 1

Consider an application that transmits data at a steady rate (for example, the sender generates an N-bit unit of data every k time units, where k is small and fixed). Also, when such an application starts, it will continue running for a relatively long period of time. Answer the following questions. Briefly justifying your answer:

a. Would a packet-switched network or a circuit-switched network be more appropriate for this application? Why?

b. Suppose that a packet-switched network is used and the only traffic in this network comes from such applications as described above. Furthermore, assume that the sum of the application data rates is less than the capacities of each and every link. Is some form of congestion control needed? Why?

Problem 2

Consider two hosts, A and B, connected by a single link of rate R bps. Suppose that the two hosts are separated by m meters, and suppose the propagation speed along the link is s meters/sec. Host A is to send a packet of size L bits to Host B.

a. Ignoring processing and queuing delay, obtain an expression for the end-to-end delay.

b. Suppose s=2.5*10^8 meters/sec, L=120 bits, and R=56kbps. Find the distance m so that the propagation delay equals transmission delay.

Problem 3

We consider sending real-time voice from Host A to Host B over a packet-switched network (VoIP). Host A converts analog voice to a digital 64kpbs bit stream on the fly. Host A then groups the bits into 56-byte packets.There is one link between Hosts A and B, its transmission rate is 2Mbps and its propagation delay is 10msec. As soon as Host B receives an entire packet. It converts the packet's bit to an analog signal. How much time elapses from the time a bit is created (from the original analog signal at Host A) until the bit is decoded (as part of the analog signal at Host B)?

Problem 4

In modern packet-switched networks, including the Internet, the source host segments long application-layer message (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. Consider a message that is $8*10^6$ bits long that is to be sent from Host A to Host B with two packet-switches in between. Suppose each link is 2Mbps. Ignore propagation, queuing, and processing delays.

a. Consider sending the message from A to B without message segmentation. How long does it take to move the message from Host A 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 A to B?

b. Now suppose that the message is segmented into 800 packets, with each packet being 10,000 bits long. How long does it take to move the first packet from A 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 A 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 A to B when message segmentation is used? Compare this result with your answer in part (a) and comment.

d. In addition to reducing delay, what are reasons to use message segmentation?

e. Discuss the draw-backs of message segmentation.