Solutions to Chapter 1 Problems

Q1. 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?

(This question is taken from Kurose & Ross's book, Chapter 1 Problem 3)

Solution

a) A circuit-switched network would be well suited to the application, because the application involves long sessions with predictable smooth bandwidth requirements. Since the transmission rate is known and not bursty, bandwidth can be reserved for each application session without significant waste. In addition, the overhead costs of setting up and tearing down connections are amortized over the lengthy duration of a typical application session.

b) In the worst case, all the applications simultaneously transmit over one or more network links. However, since each link has sufficient bandwidth to handle the sum of all of the applications' data rates, no congestion (very little queuing) will occur. Given such generous link capacities, the network does not need congestion control mechanisms.

Q2. 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.

(This question is taken from Kurose & Ross's book, Chapter 1 Problem 6, parts c and g)

Solution:

a) $d_{end-to-end} = (m/s + L/R)$ seconds.

d) Want

$$m = \frac{L}{R}s = \frac{120}{56\times10^3}\left(2.5\times10^8\right) = 536\,\text{km}.$$

Q3 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)?

Solution:

Consider the first bit in a packet. Before this bit can be transmitted, all of the bits in the packet must be generated. This requires

$$\frac{56 \cdot 8}{64 \times 10^3} \text{ sec=7msec.}$$

The time required to transmit the packet is

$$\frac{56 \cdot 8}{2 \times 10^6} \text{ sec} = 224 \mu \text{ sec.}$$

Propagation delay = 10 msec.
The delay until decoding is

$7\text{msec} + 224 \mu \text{ sec} + 10\text{msec} = 17.224\text{msec}$

A similar analysis shows that all bits experience a delay of 17.224 msec.

Q4. 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? Discuss the draw-backs of message segmentation.

Solution:

a) Time to send message from source host to first packet switch $= \dfrac{8 \times 10^6}{2 \times 10^6} \sec = 4 \sec$

With store-and-forward switching, the total time to move message from source host to destination host $= 4 \sec \times 3\, hops = 12 \sec$

b) Time to send 1st packet from source host to first packet switch $=$. $\dfrac{1 \times 10^4}{2 \times 10^6} \sec = 5\, m\sec$. Time at which 2nd packet is received at the first switch $=$ time at which 1st packet is received at the second switch $= 2 \times 5 m\sec = 10\, m\sec$

c) Time at which 1st packet is received at the destination host $= 5\, m\sec \times 3\, hops = 15\, m\sec$. After this, every 5msec one packet will be received; thus time at which last (800th) packet is received $= 15\, m\sec + 799 * 5 m\sec = 4.01 \sec$. It can be seen that delay in using message segmentation is significantly less (almost $1/3^{rd}$).

d)
   i. Without message segmentation, if bit errors are not tolerated, if there is a single bit error, the whole message has to be retransmitted (rather than a single packet).
   ii. Without message segmentation, huge packets (containing HD videos, for example) are sent into the network. Routers have to accommodate these huge packets. Smaller packets have to queue behind enormous packets and suffer unfair delays.

e)
   i. Packets have to be put in sequence at the destination.
   ii. Message segmentation results in many smaller packets. Since header size is usually the same for all packets regardless of their size, with message segmentation the total amount of header bytes is more.