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Problem Set #1

Due Tuesday Sept 17th by 12:30pm

Assume that 1 Kbps = 10^3 bits/sec, 1 Mbps = 10^6 bits/sec, 1 Gbps = 10^9 bits/sec, and 1MB = 10^6 x 8 bits. The capital 'B' typically means 'byte' while the lowercase 'b' indicates 'bit'.

1. (3pts) What advantage does a circuit-switched network have over a packet-switched network?

   Circuit switching has the advantage of establishing a dedicated circuit across a sequence of links and then allows the source node to send a stream of bits across this circuit to the destination node.

2. (3pts) What advantage does TDM have over FDM in a circuit switched network?

   In TMD, time is divided into equal amounts/frames and each flow is given a fixed duration in which to send its data over the link. FDM divides the frequencies so each flow can transmit data at different frequencies. The advantage TDM has over FDM for a circuit-switched network is the capability to use the entire bandwidth.

3. (21pts) Consider two hosts, A and B, which are connected by a link (**R** bps). Suppose that the two hosts are separated by **m** meters, and the speed along with link is **s** meters/sec. Host A is to send a packet of size **L** bits to Host B.

   a. Express the propagation delay, d_{prop}, in terms of m and s.

      d_{prop} = m / s – seconds

   b. Determine the transmission time of the packet, d_{trans}, in terms of L and R.

      d_{trans} = L / R – seconds

   c. Ignoring processing and queuing delays, obtain an expression for the end-to-end delay (one-way delay from Host A to Host B)

      Latency = m / s + L / R – seconds

d. Suppose Host A begins to transmit the packet at time t = 0, At time $t = d_{trans}$, where is the last bit of the packet?

Since $d_{trans} = L / R$ – seconds, the last bit of the packet would be leaving host A

e. Suppose d_{prop} is greater than d_{trans} . At time $t = d_{trans}$, where is the first bit of the packet?

$d_{prop} = m / s$ – seconds

$d_{trans} = L / R$ – seconds

$m / s > L / R$

Therefore, the first bit has not reached Host B and the packed is still in the link.

f. Suppose d_{prop} is less than d_{trans} . At time $t = d_{trans}$, where is the first bit of the packet?

$d_{prop} = m / s$ – seconds

$d_{trans} = L / R$ – seconds

$m / s < L / R$

Therefore, the first bit would have just reached Host B

g. Suppose $s = 2.5 * 10^8$, L = 120bits, and R = 56Kbps. Find the distance m so that d_{prop} equals d_{trans}.

$d_{prop} = d_{trans}$

$m / s = L / R$

m = (2.5 x 10^8 m/s) * (120 b/ 56xx10^3 b/s)

m = 535714.28- m → 540 Km

4. (8pts) We consider sending real-time voice from Host A to Host B over a packet-switched network. Host A converts analog voice to a digital 65kbps bit stream and send these bits into 56-byte packets. There is one link between Hosts A and B and the transmission rate is 1 Mbps and its propagation delay is 20 msec. As soon as Host A gathers a packet, it sends it to Host B. As soon as Host B receives an entire packet, it converts the packet's bits into 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)?

t = dprop + transmit packet time + bit conversion time

t = 20 –ms + 56*8/10^6 –s + 56*8/65*10^3=s

t = 20 -ms + 0.45 -ms + 6.8 -ms

t = 27.25 -ms → 27 -ms

5. (12pts) Consider a Go-Back-N sliding window algorithm (1 packet is 250 bytes long) running over a 100km point-to-point fiber link with bandwidth of 100 Mbps.

   a. Compute the one-way propagation delay for this link, assuming that the speed of light is 2 x 10^8 m/s in the fiber.

      dprop = 100 -Km / 2*10^8 -m/s

      dprop = 0.5 -ms

   b. Suggest a suitable timeout value for the algorithm to use. List factors you need to consider.

      If the receiver has received N packets (the size of the window) the acknowledgment number will be N+1. It is important that the acknowledgment timer will not start after the expiry of the first timer. The timeout timer should be greater than the acknowledgment timer. The time out should be RTT of the time it takes the sender to send N packets + the time it takes the receiver to generate and send the acknowledgment message (and for that message to have reached the sender).

   c. Suggest N to achieve 100% utilization in this link.

      U = N * dframe / (2*dprop + dframe)

      dframe is the delay between each packet sent

      dprop is the propagation delay

      U is the utilization rate

      N = U * (2*dprop + dframe) / dframe

      N = (2 * (100Km/2*10^8m/s) + ((250 bytes) / 100 Mbps)) / ((250 bytes) / 100 Mbps)

      N = 51

6. (12pts) Suppose a 1-Gbps point-to-point link is being set up between the Earth and a new lunar colony. The distance from the moon to the Earth is approximately 385,000 km, and data travels over the link at the speed of light—3×10^8 m/s.

   a. Calculate the minimum RTT for the link.

      RTT = 2 * 385,000 -Km / 3.0*10^8 -m/s

      RTT = 2.567 -s → 2.57 seconds

   b. Using the RTT as the delay, calculate the delay × bandwidth product for the link.

      delay x bandwidth = RTT * 1 -Gbps

      dxb = 2.57 -Gb

   c. What is the significance of the delay × bandwidth product computed in (b) ?

      The delay x bandwidth product signifies the amount of data a sender can send before receiving acknowledgment that the receiver received the first bit.

7. (12pts) Host A wants to send a 1,000 KB file to Host B. The Round Trip Time (RTT) of the Duplex Link between Host A and B is 160ms. Packet size is 1KB. A handshake between A and B is needed before data packets can start transferring which takes 2xRTT. Calculate the total required time of file transfer in the following cases. The transfer is considered complete when the acknowledgment for the final packet reaches A.

   a. The bandwidth of the link is 4Mbps. Data packets can be continuously transferred on the link.

      t = 2*160 -ms + 1000*(1 -KB / 4 -Mbps)

      t = 2.32 -seconds

   b. The bandwidth of the link is 4Mbps. After sending each packet, A need to wait one RTT before the next packet can be transferred.

      t = 2*160 -ms + 1000*(160 -ms + 1 -KB / 4 -Mbps)

      t = 162 -seconds

c. Assume we have “unlimited” bandwidth on the link, meaning that we assume transmit time to be zero. After sending 50 packets, A need to wait one RTT before sending next group of 50 packets.

t = (1000 -pkts/ 50 -pkts) * 160

t = 3.2 -seconds

d. The bandwidth of the link is 4Mbps. During the first transmission A can send one (2^{1-1}) packets, during the 2^{nd} transmission A can send 2^{2-1} packets, during the 3^{rd} transmission A can send 2^{3-1} packets, and so on. Assume A still need to wait for 1 RTT between each transmission.

2^n-1 → 1000^{th} packet sent on 10^{th} round

t = 2*160 -ms + 10*(160 -ms + 1 -KB / 4 -Mbps)

t = 1.94 -seconds

8. (5pts) Determine the width of a bit on a 10 Gbps link. Assume a copper wire, where the speed of propagation is $2.3 \ast 10^8$ m/s.

width = speed of prop / R

width = 2.8 * 10^8 -m/s/ 10 -Gbps

width = 0.023 -m/b

9. (12 pts) Suppose two hosts, A and B, are separated by 20,000 kilometers and they are connected by a direct link of R=1Gbps. Suppose the propagation speed over the link is 2.5×10^8 meters/sec.

a. Calculate the bandwidth delay product (BDP) of the link.

BDP = dprop * R

BDP = (20000 -Km / 2.5*10^8 -m/s) * 2 -Mbps

BDP = 160,000 -b → 160 -Kb

b. Consider sending a file of 800,000 bits from Host A to Host B as one large message. What is the maximum number of bits that will be in the link at any given time?

The BDP is the maximum number of bits that can be in the link. Therefore, only 160 -Kb can be in the link at at any given time.

c. What is the width (in meters) of a bit in the link?

width = 20000 -Km / 160 -Kb

width = 125 -m/b

d. Suppose now the file is broken up into 20 packets with each packet containing 40,000 bits. Suppose that each packet is acknowledged by the receiver and the transmission time of an acknowledgment packet is negligible. Finally, assume that the sender cannot send a packet until the preceding one is acknowledged. How long does it take to send the file.

t = 20 * (RTT + 40-Kb / R)

t = 20 * (20000 -Km / 2.5*10^8 -m/s + 40 -Kb / 1 -Gbps)

t = 1.601 -seconds

10. (12 pts) Suppose there is a 10 Mbps microwave link between a geostationary satellite and its base station on Earth. Every minute the satellite takes a digital photo and sends it to the base station. Assume a propagation speed of 2.4 x 10^8 meters/sec. Geostationary satellite is 36,000 kilometers away from earth surface

a. What is the propagation delay of the link?

dprop = distance / speed

dprop = 36,000,000 -m / 2.4*10^8 -m/s

dprop = 0.15 -seconds

b. What is the bandwidth-delay product, R x (propagation delay)?

BDP = R * dprop

BDP = R * m / s = 10 Mbps * 0.15

BDP = 1,500,000 bits → 1.5 Mb

c. Let *x* denote the size of the photo. What is the minimum value of *x* for the microwave link to be continuously transmitting?

1 photo / min → 1 photo / 60 seconds

x = 10 Mbps x 60 -s

x = 600,000,000 bits → 600 Mb