EE4204/TEE4204/EE4204E Computer Networks(Part 1)

Semester 1, 2021-22

TUTORIAL 1: PROBLEMS & SOLUTIONS

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Problem 1

- Problem:
  - It is desired to stream an uncompressed video at full HD (high definition) resolution 1920×1080 pixels with 30 fps (frames per second). How much bandwidth (data rate) is required for this purpose?
- <u>Solution:</u>
  - Generally, a pixel (picture element) is a mix of three colors (red, green, blue) with each color in the range [0..255]. Thus, we need $3 \times 8 = 24$ bits to represent a pixel.
  - Therefore, bandwidth required $= 1920 \times 1080 \times 24 \times 30$

    $= 1.49$ Gbps

Problem 2

- ## Problem:
  - Suppose a 100 Mbps 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 camera on the lunar base takes pictures of the earth and saves them in digital format to disk. Suppose *Mission Control* on earth wishes to download the most current image, which is 25 MB. What is the minimum amount of time that will elapse between when the request for the data goes out and the transfer is finished? Determine the effective throughput for the above case.

Problem 2 (contd.)

- Solution:
  - Transmission time = 25 MB / 100 Mbps = 2.097 s
  - Propagation time from the earth to lunar base

    = 385,000 km / (3×10^8 m/s) = 1.283 seconds
  - RTT = 2×1.283 = 2.566 seconds.
  - The transfer time includes the propagation time for the request to go from the earth to lunar base, image transmission time, and propagation time from the lunar base to the earth. Therefore, the transfer requires 1 RTT plus transmission time = 2.566+2.097 = 4.663 seconds.
  - Effective Throughput = (Message size / Message transfer time) = 25 MB/ 4.663 = 44.974 Mbps

Problem 3

- Problem:
  - How many 10-Mbps inputs can be multiplexed onto an 100-Mbps output in cases (i) fixed TDM and (ii) statistical TDM?

- Solution:
  - Fixed TDM: At most ten 10-Mbps inputs can be multiplexed onto an 100-Mbps output
  - Statistical TDM: There is no limit on the number of 10-Mbps inputs that can be multiplexed onto an 100-Mbps output. It depends on how active the inputs are and how much buffer is available to queue the excess traffic when the sum of the input data rates exceeds the output data rate.

Problem 4

- Problem:
  - A 20km long link is able to hold only 100 bits in one direction. What is the bandwidth of the link? Assume that the propagation speed on the link is 2×10^8m/s.
- Solution:
  - Number of bits that can be held = (propagation) delay $\times$ bandwidth
  - Therefore, bandwidth = (No of bits held on the link / propagation time) = $100 / (20000/[2 \times 10^8]) = 1$ Mbps

Problem 5

- Problem:
  - A disadvantage of a broadcast network is that the capacity is wasted due to multiple hosts attempting to access the channel at the same time. As a simplistic example, suppose that time is divided into discrete slots, with each of the n hosts attempting to use the channel with probability p during each slot. What fraction of the slots is wasted due to collisions only?

Problem 5 (contd.)

- Solution:
  - Binomial probability B(n,r): probability of exactly r successes on n trails (with p the success probability on a trial)
    - $B(n,r) = nCr\ p^r\ (1-p)^{n-r}$
  - p = probability that a host attempts to use the channel in a slot
  - q_0 = probability that no host attempts to use the channel in a slot = B(n,0)
  - q_1 = probability that exactly one host attempts to use the channel in a slot = B(n,1)
  - q = probability for collision occurrence in a slot
  - Collision occurs when two or more hosts attempt to use the channel during a slot. Therefore, q = B(n,2)+B(n,3)+…+B(n,n)

    $q = 1 - [\ q_0 + q_1\ ]$

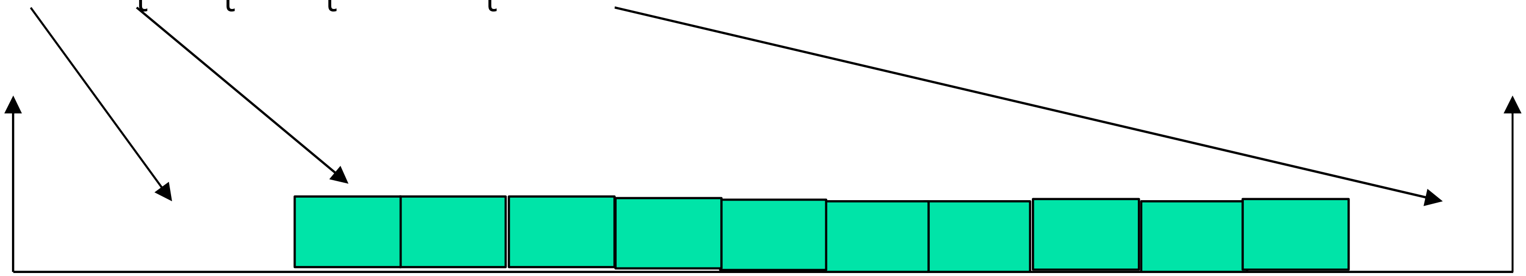
    $\quad = 1 - [\ (1-p)^n + n \times p \times (1-p)^{n-1}\ ]$

Problem 6

- Calculate the total time required to transfer a 1000 KB file in the following cases, assuming an RTT of 100 ms, a packet size of 1 KB of data, and an initial $2\times$RTT of "handshaking" before data is sent.
  - (a) The bandwidth is 1.5 Mbps, and data packets can be sent continuously.
  - (b) The bandwidth is 1.5 Mbps, but after we finish sending each data packet we must wait one RTT before sending the next.

Problem 6T_t (Contd.)

- Number of packets = 1000, RTT = 100 ms
- Packet transmission time T_t = 1KB/1.5 Mbps = 5.461 ms
- (a) Total time (T) required is initial RTTs plus transmission time of 1000 packets plus propagation time (for 1000th packet) from sender to receiver plus propagation time from receiver to sender (for acknowledgement). Therefore, T = 2 RTTs+ 1000×5.461 ms + RTT = 5.761 seconds.
- 2RTT+T_t +T_t + T_t +…+T_t+ RTT

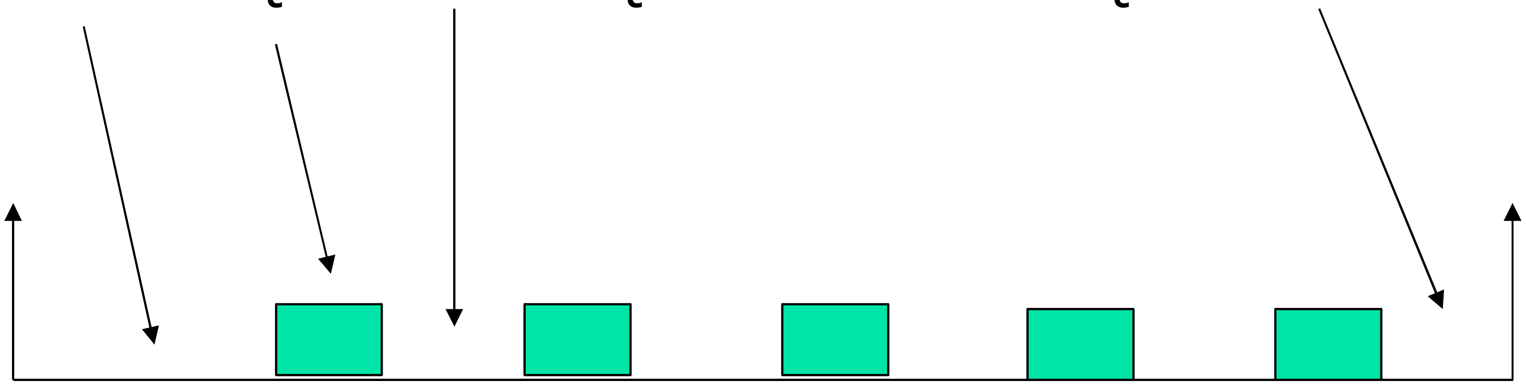


Problem 6 (Contd.)

- (b) T = 2 RTTs + 1000 $\times$ packet transmission time + 1000 RTTs

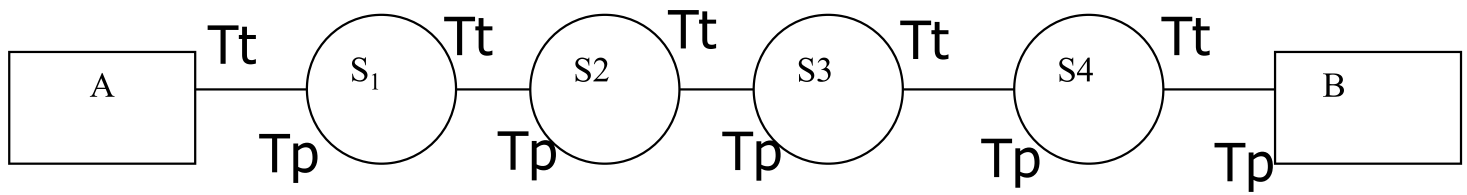
  = 100.2+5.461 = 105.661 seconds.

- $2RTT+T_t +RTT+T_t +RTT+\ldots+T_t+ RTT$



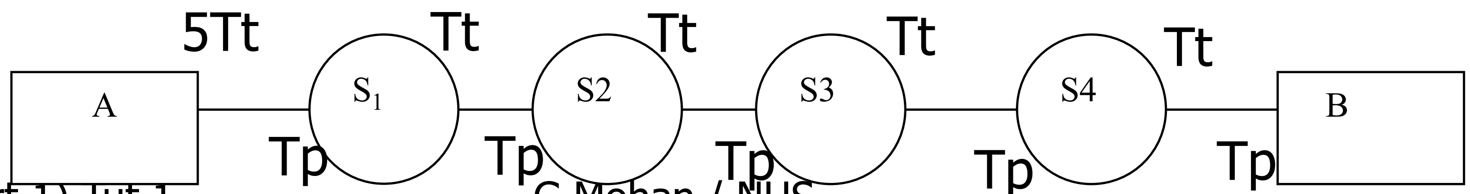
Problem 7

- Problem: Calculate the latency (from first bit sent to last bit received) for the following:
  a) A packet of 5000 bits is sent over a 10 Mbps Ethernet from node A to node B through four store-and-forward switches in the path as shown in the following figure. Assume that each link introduces a propagation delay of 10 μs, and that the switch begins retransmitting immediately after it has finished receiving the packet.
- Solution:
  - Packet transmission time Tt = 5000bits/10Mbps = 500 μs.
  - Propagation delay on one link Tp = 10 μs.
  - The packet traverses 5 links. It needs to be transmitted at 5 nodes (1 source and 4 switches). Therefore, latency = $5 \times 10 + 5 \times 500$ μs = 2.55 ms.



Problem 7 (contd.)

- Problem: Calculate the latency (from first bit sent to last bit received) for the following:
  - b) Same as (a), but 5000 bits are sent in 5 packets each carrying 1000 bits. The packets are transmitted continuously with no time gap between two consecutive packet transmissions.
- Solution:
  - Packet transmission time Tt = 1000bits/10Mbps = 100 μs.
  - Propagation delay on one link Tp = 10 μs.
  - Node A completes transmission of last packet at $5 \times 100 = 500\mu$s. The last packet needs to transmitted at each of the 4 switches. This packet experiences propagation delay at each of the 5 links.
  - Therefore, latency = $500 + 4 \times 100 + 5 \times 10$ μs = 950 μs



Problem 7 (contd.)

- **Problem:** Calculate the latency (from first bit sent to last bit received) for the following:
  - c) Same as (a), but assume that each switch implements "cut-through" switching: It is able to begin retransmitting the packet immediately after receiving the first 200 bits.
- **Solution:**
  - The packet is delayed for a period of "packet transmission" time (Tt=500 μs) at the source A and is delayed for a period of 200 bits time at each of the 4 switches. The packet experiences propagation delay (Tp = 10 μs) at each of the five links.
  - 200 bit delay (T_{200}) = 200bits/10Mbps = 20 μs
  - latency = 500 + 4×20 + 5×10 μs = 630 μs