Introduction to Computer Networks **Name:** _____
Fall 2019
Homework 1 (Due: 11/15/2019) **ID:** _____

This homework contains 8 questions. The deadline is on Nov. 12 (Tue) at 23:59. Please submit your answers to *gradescope*.

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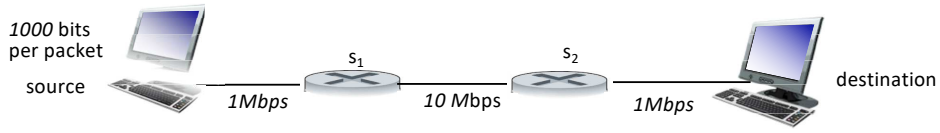
1. (5 points) **Medium Access:** Define what is FDM and TDM. Explain what is the difference between FDM and TDM.

2. (15 points) **Packet Switching:** Consider a packet-switching network.
   (a) (5 points) Define what is store-and-forwarding.

   (b) (5 points) Consider the following scenario. Assume there is no propagation delay and nodal processing delay. If a packet of 1,000 bits is sent by the source, how long does it take to completely arrive the switch s_2. (Show your derivation)



(c) (5 points) Consider the same network. Assume that each switch has an infinitely large buffer. If the source now sends 10 back-to-back packets at time 0, what is the time that the destination receives all the 10 packets. (Show your derivation)

3. (10 points) **Queueing delay:**

(a) (5 points) Define what is traffic intensity.

(b) (5 points) Consider the following two networks. Packets will experience queueing delay in which network and which switch. Why?

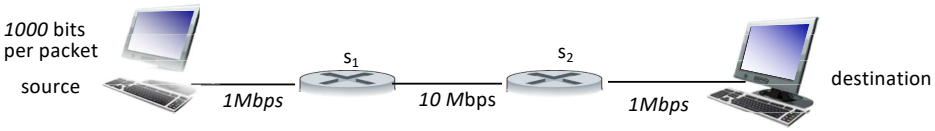


Figure 1: network 1

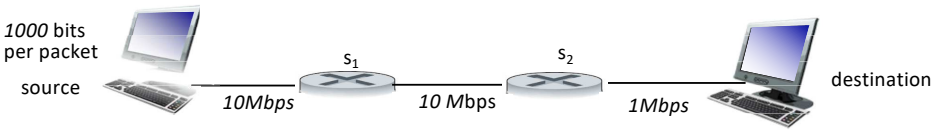


Figure 2: network 2

4. (15 points) **Application layer:**
   (a) (3 points) Explain what is the difference between the "server-client" architecture and the "peer-to-peer" architecture.

   (b) (3 points) Define what is the "single-point failure problem".

   (c) (3 points) Explain why do we need a unique port number for every process in a host.

   (d) (6 points) Define what is a "distributed" system. Define what is a "hierarchical" system. Give one advantage of a distributed system. Give one advantage of a hierarchical system.

5. (15 points) **HTTP:**
   (a) (5 points) Explain what is the difference between persistent HTTP and non-persistent HTTP. Which one spends more handshaking latency?

(b) (5 points) Define what is RTT. Explain why asking for downloading an HTTP object requires two RTTs.

(c) (5 points) By default, HTTP is a "stateless" service. (a) Explain what does it mean. (b) If a server wants to keep user information, what protocol it can use?

6. (5 points) **Peer-to-peer:** Define what does tit-for-tat in a BitTorrent system mean? Why it can prevent the free-riding problem?

7. (15 points) **Video streaming:**

(a) (5 points) Explain what is the difference between video-on-demand and real-time video streaming.

(b) (5 points) Why CDN can help improve the visual quality of video streaming? Explain what is the difference between "geographical distance" and "end-to-end path length".

(c) (5 points) Explain what does "auto-rate (adaptation)" in DASH (HTTP streaming) mean. Auto-rate is done by the client or the server?

8. (20 points) **Reliable data transfer:**

(a) (3 points) Explain what is the difference between bit errors and packet losses.

(b) (2 points) In the following cases, which cases could trigger unnecessary retransmissions? (multiple choices)

1. The sender receives a corrupted feedback from the receiver.
2. The sender receives a corrected ACK from the receiver.
3. The sender sends a packet and sets a timeout to 1ms, while the receiver does not receive any packet.
4. The sender sets a timeout shorter than RTT.

(c) (5 points) Consider a scenario where the end-to-end bit error rate is 0.003. Assume a source sends a packet of 100 bits to the destination. What is the final packet error probability if the sender can retransmit the packet at most twice (i.e., overall 3 transmissions including the original transmission). (Hint: $0.997^{100} = 0.7405$, $0.997^{10} = 0.9704$, $(1 - 0.7405)^3 = 0.0175$, $(1 - 0.7405)^4 = 0.0045$, $(1 - 0.7405)^5 = 0.0012$, $(1 - 0.9704)^3 =$

$2.5934e-05$, $(1-0.9704)^4 = 7.6766e-07$, $(1-0.9704)^5 = 2.2723e-08$, $0.9704^3 = 0.9138$, $0.9704^4 = 0.8868$, $0.9704^5 = 0.8605$)

(d) (10 points) Following the previous question, assume now we still transmit packets of 100 bits, but redefine "reliable transmission" as achieving the expected packet success probability of 99%. (a) What is the minimal number of retransmissions we need to guarantee reliable transmission. (b) Assume we limit the retransmission count to the above minimal required number of retransmissions, what is the expected number of retransmissions?