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# CS144
# Introduction to Computer Networking
# Midterm Exam — Thursday, May 11th, 2023

**Rules: 2 note pages, closed book, no Internet, computers off**

**Your Name:** ______________________________

**SUNet ID:** ______________________ `@stanford.edu`

**On my honor, and in accordance with the letter and spirit of the Stanford Honor Code, I neither received nor provided any assistance on this exam.**

**Signature:** ______________________________

Check if you would like exam routed back via SCPD: ☐

- The exam has 4 questions totaling 58 points.
- You have 90 minutes to complete them.
- Please keep your answers concise. You may lose points for a correct answer that also includes incorrect or irrelevant information.
- If you would like to make any additional commentary on a multiple-choice answer, please write it below the answer section, but nothing additional is necessary to receive full credit.
- Please box your final answers.

| | |
|---|---|
| **1** | /19 |
| **2** | /15 |
| **3** | /12 |
| **4** | /12 |
| **Total** | /58 |

# I TCP

**1. [19 points]:**

Alice initiates a TCP connection with Bob and wants to transmit the 12-byte stream "Good morning" (including the space) in as few segments as possible. Bob wants to transmit the 5-byte stream "Hello" to Alice, also in as few segments as possible. These strings represent the entire stream that each peer wants to send. Alice assumes that Bob's initial window size is 1. This is the first segment that Alice sends to Bob:

| | |
|---|---|
| seqno=10 | ACK=false |
| SYN=true | ackno=∅ |
| data="" | window size=4 |
| FIN=false | |

(a) What should Bob send in response to Alice? Fill in the blanks.

| | |
|---|---|
| seqno=42 | ACK=true |
| SYN=true | ackno=_______ |
| data=_______ | window size=3 |
| FIN=_______ | |

(b) What are the next two segments they should exchange? Assume no packets are dropped.

From Alice:

| | |
|---|---|
| seqno=_______ | ACK=_______ |
| SYN=_______ | ackno=_______ |
| data=_______ | window size=4 |
| FIN=_______ | |

From Bob:

| | |
|---|---|
| seqno=_______ | ACK=_______ |
| SYN=_______ | ackno=_______ |
| data=_______ | window size=3 |
| FIN=_______ | |

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(c) Consider the connection to be complete when both Alice and Bob have received an acknowledgement for their FIN flag from the other party.

If Alice always advertises a window size of 4, and Bob always advertises a window size of 3, then: what's the smallest number of segments Alice can send (including the first segment and any acknowledgment-only segments) before the connection is complete? What about for Bob?

Alice sends: _______ segments in total
Bob sends: _______ segments in total

(d) What is the smallest number of segments that each party could send in the entire connection, if instead Alice assumed that Bob's initial window size was 1000, and Alice advertised a window size of 1000 in her outgoing segments?

Alice: _______
Bob: _______

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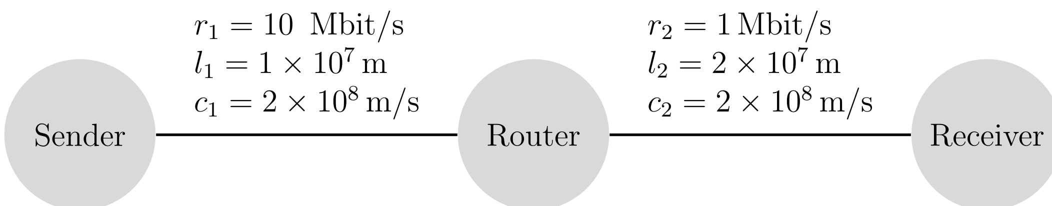
# II Packet Switching

In this problem, we'll consider a single flow over a top-hop network path. The router is "normal" and processes each packet as a unit (the entire packet must arrive before it can begin being sent on an outgoing link).




Arithmetic helper: $\frac{10^7 \text{m}}{2\times10^8 \text{m/s}} = \frac{10^{-1}}{2}$ s $= 0.05$ s $= 50$ ms

**2. [15 points]:**

(a) Assume there is no other traffic in the network. If the sender sends a single packet of size 10 kbit to the receiver, how long does it take until the packet fully arrives? (In other words, what is its total end-to-end delay?) Please express your answer in milliseconds.

(b) If the sender sends two packets back to back, both of size 10 kbit, how long does it take until the second packet fully arrives at the receiver? Again, please express your answer in milliseconds.

(c) In question (b), what is the queueing delay that packet $p_2$ experiences at the router (in milliseconds)?

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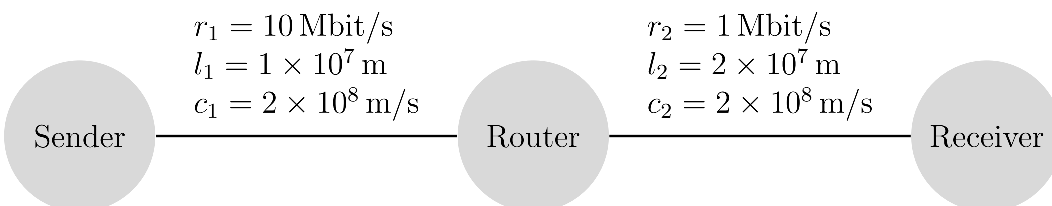
# III Congestion Control

Let's again consider our single flow over the same two-hop network path. Assume that the total propagation delay is symmetric, so the delay for an acknowledgement to go from the receiver back to the sender is equal to the forward-path propagation delay (i.e., no queuing delays in the reverse path), and that the size of any individual packet is negligible.




Arithmetic helper: $\frac{10^7 \text{m}}{2 \times 10^8 \text{m/s}} = \frac{10^{-1}}{2}\ \text{s} = 0.05\ \text{s} = 50\ \text{ms}$

**3. [12 points]:**

(a) If the Sender uses a constant congestion window size, what would be the "ideal" window size for it to choose? (A value that keeps the link fully utilized, with zero queueing.) Please express your answer in **kilobits**.

(b) Assume the Sender uses the Additive Increase Multiplicative Decrease congestion-control method we learned in class. When encountering a loss, the Sender cuts its congestion window size in half. When receiving an acknowledgment for newly received data, the sender slowly increases its window size (by 1 full-sized segment every RTT).

Given this, what is the "ideal" buffer size for the Router to have (maximum queue occupancy before packets are dropped) such that the link remains always fully utilized, but queueing is as small as possible?

Express your answer in **kilobits**.

(c) How much data "in flight" would you expect the Sender to have immediately **before** it experiences a loss? Again, please express your answer in kilobits.

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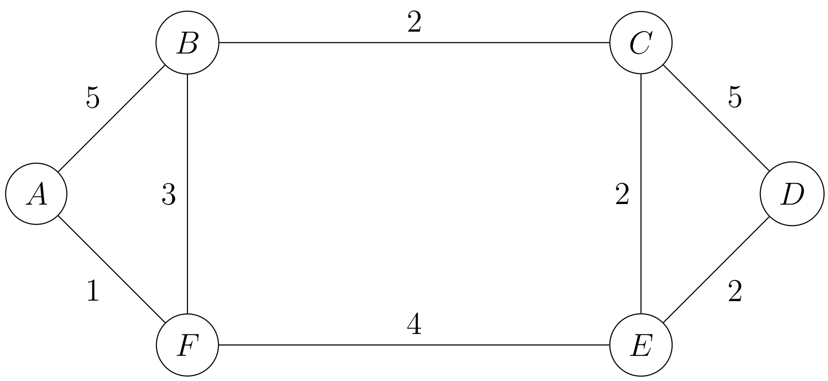
# IV Routing

**4. [12 points]:**

Please see the network diagram below. The nodes represent routers, and the numbers next to each link represent the link's cost. Throughout the following questions, you can interpret "shortest" and "longest" to mean "lowest-cost" and "highest-cost."




(a) For which pair of routers is the lowest-cost path between them the largest? Please give your answer as a pair of router names; for example (A, B).

(b) What is the cost of this path (the lowest-cost path between the two routers you identified in part (a))? Please give your answer as a single positive integer.

(c) What is the minimum number of links that would need to fail at the same time to prevent a pair of routers from being able to communicate with each other?

(d) Imagine this network uses the simplified form of the Bellman-Ford algorithm that we saw in lecture to build its routing tables, in which all routers exchange information with their neighbors in lock-step. If all routers start from scratch (i.e., distance vectors initialized to infinity), how many steps will it take for the network to reach its final routing table configuration? Please give your answer as a single positive integer.