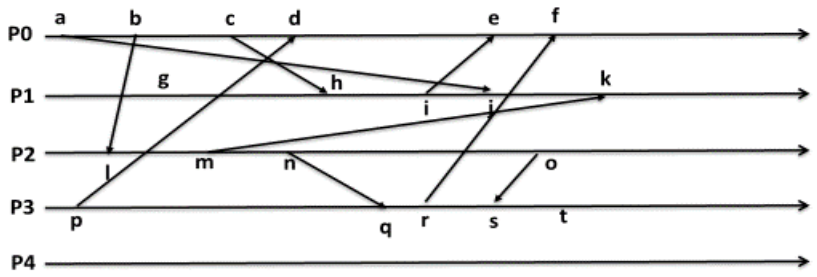
CSCI/ECEN 5673: Distributed Systems
Spring 2022
Homework 2 (Solutions)
Due Date: 03/01/2022

Please submit a PDF copy of your answers via the submission link on Canvas by March 01, 2022. Write your answers in the space provided. Please DO NOT use any extra space. The space provided is sufficient for answering the questions.

Honor Code Pledge: On my honor, as a University of Colorado at Boulder student, I have neither given nor received unauthorized assistance on this work.

Name:

1. Consider the following figure from Homework 1 that shows five processes ***(P0, P1, P2, P3, P4)*** with events ***a, b, c,*** ... and messages communicating between them.



a) **[15 Points]** Identify two messages between *different* pairs of processes, i.e. m1 between Pi, Pj and m2 between Pj, Pk, such that Pi ≠ Pj ≠ Pk and m1 and m2 are causally related.

<bl> and <nq>
<bl> and <os>
<bl> and <mk>
<nq> and <rf>

b) Is there a violation of FIFO ordering between messages in this figure? If yes, provide one example of the corresponding messages.

Yes
<a,j> and <c,h>

c) Is there a violation of causal ordering between messages in this figure? If yes, provide one example of the corresponding messages. Your example should not include the messages where there is a violation of FIFO ordering.

No violation of causal ordering

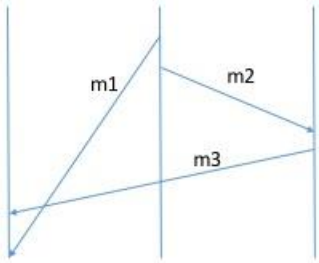
d) Provide a total ordering of messages that preserves causal ordering in this figure. Is your total ordering unique? If not, provide a different total ordering of messages that preserves causal ordering.

aj, bl, ch, dp, mk, nq, ie, rf, os

No, e.g. aj and dp above can be exchanged

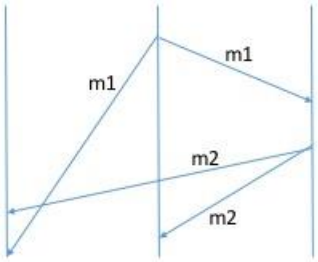
2. Suppose an underlying communication system provides a reliable, FIFO message communication.
    a) If the underlying communication system provides only unicast message exchanges, does it preserve causal ordering among messages? If yes, provide supporting arguments, if no, provide a counter example.

No.
Send (m1) → Send(m3)
But m3 is received before m1



    b) If the underlying communication system provides multicast, does it preserve causal ordering among messages? If yes, provide supporting arguments, if no, provide a counter example.

No.
Send (m1) → Send(m2)
But m2 is received before m1



3. Psync provides causal delivery of messages exchanged with in a group of processes. In class it was mentioned that you can construct a total order of message delivery from the context graph by using topological sort. Explain how this can be done. Your algorithm should not use any extra messages.

This is covered in the Psync paper. Perform topological sort of a layer (called wave in the paper) in the context graph when all the nodes of that layer are in the graph (called stable wave in the paper).

To find out if all nodes of a layer (say layer L) are in the graph, check if there is a node for each group member (node representing a message send by the member) in layer L or a layer following L.

4. Consider the consensus algorithm for synchronous distributed systems under scenario 3 that we discussed in class. Construct an example to show that the processes may not reach a consensus in *f* rounds with *n* processes, $n > f$.

Assume n = 3 processes, P0, P1 and P2; Initial values of P0 and P1 are 1 and initial value of P2 is 0. Further assume f = 1.

In round 1: P0 sends its vector to P1 and then fails (before sending its vector to P2)
After round 1: vector of P1 will be [1, 1, 0] while the vector of P2 will be [u, 1, 0].
Based on majority rule, P1 will decide consensus value as 1 but P2 will decide the consensus value as 0.

5. State the safety and liveness properties for the following applications.
   a) A distributed repository of personnel data that provides personnel information to the authorized users.

      Safety: The system will never provide personnel information to unauthorized users.
      Liveness: An authorized user will eventually get the personnel information after he/she requests it.

   b) A highly available airline reservation system that allows clients to book seats.

      Safety: A seat will never be booked by more than one client.
      Liveness: A client will be able to book a seat assuming one is available

   c) An air traffic control system that manages plane landings and takeoffs.

      Safety: A plane will never be allowed to land or takeoff when another plane is landing or taking off.
      Liveness: A plane will eventually get permission to land or takeoff