

CS 425/ECE 428 Distributed Systems
Homework 2
Due by 7 p.m. on February 9, 2016.
Submit electronically via Compass2g.

Maximum points 49

1. Consider a pair of two NTP peers synchronizing their clocks. Server B receives server A's message M at 02:00:00 bearing a timestamp 02:00:04 and replies to it by message M'. Server A receives the message M' at 02:00:08 bearing B's timestamp 02:00:03.

a) Estimate the offset between NTP servers B and A (5 points)

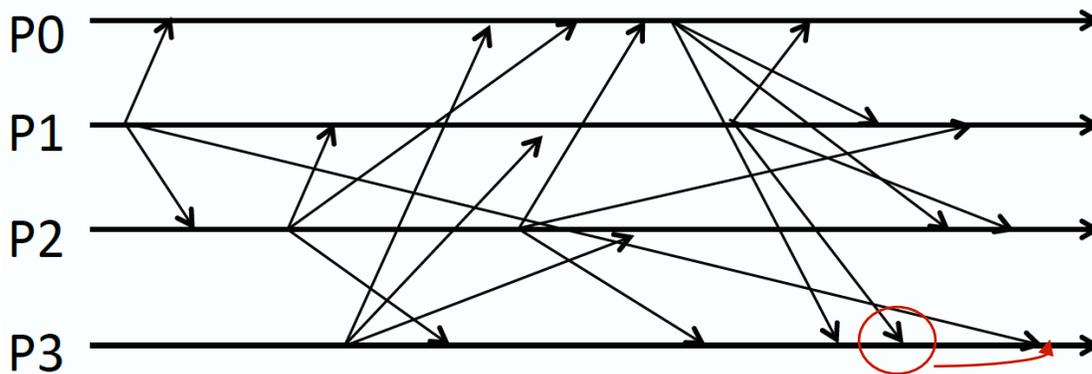
Answer: $(02:00:00 - 02:00:04 + 02:00:03 - 02:00:08) / 2 = -4.5 \text{ s}$

b) Determine the accuracy of the above estimate (5 points)

Answer: $02:00:00 - 02:00:04 - 02:00:03 + 02:00:08 = 1 \text{ s}$

2. In the execution below, processes send messages to each other to implement FIFO multicast. To simplify the picture, messages sent by each process to itself are not shown, but you may assume that such messages are received instantaneously.

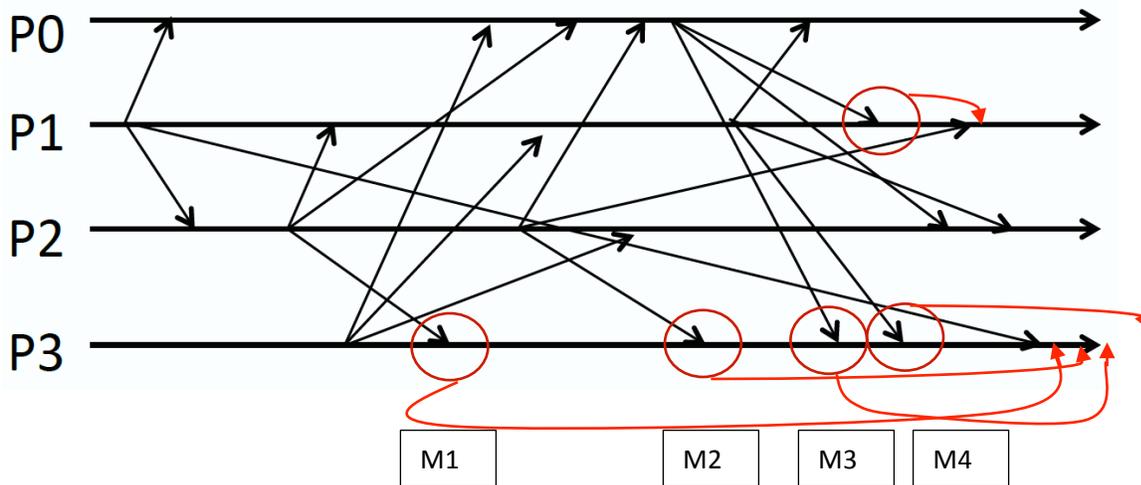
- a) Identify the messages that are buffered at the processes to ensure FIFO multicast delivery. (Circle the receive event for the buffered messages to identify those messages.) (5 points)
- b) For each message buffered as above, determine the earliest instant of time at which the message may be delivered, while ensuring FIFO multicast. (To identify the instant of time draw an arrow that begins at the time when the message is received to the time at which the message may be delivered.) (5 points)



3. In the execution below, processes send messages to each other to implement **causally-ordered multicast**. To simplify the picture, messages sent by each process to itself are not shown, but you may assume that such messages are received instantaneously.

- a) Identify the messages that are buffered at the processes to ensure causally-ordered multicast delivery. (Circle the receive event for the buffered messages to identify those messages.) (10 points)
- c) For each message buffered as above, determine the earliest instant of time at which the message may be delivered, while ensuring causally-ordered multicast. (To identify the instant of time draw an arrow that begins at the time when the message is received to the time at which the message may be delivered.) (10 points)

Causal order guarantees that M1 delivers before M2,M3,M4, and M2 delivers before M3.



4. State True or False:

- a) If a multicast service achieves total-ordering, then it also achieves causal ordering for the multicasts. (3 points)
False
- b) If a multicast service achieves causal-ordering, then it also achieves total ordering for the multicasts. (3 points)
False
- c) If a multicast service achieves causal-ordering, then it also achieves FIFO ordering for the multicasts. (3 points)
True

SUGGESTED EXERCISE (you need not submit answer to this exercise): In each part above, if you answer False, present a counter-example.