CSE 461 Homework 4

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Total points: Don't know how many points this is, assuming the max is 50, and it's 10 points each question.

1, (10 Points.)

1. Suppose the "Birman-Schiper-Stephenson Protocol" is used to enforce "Causal Ordering of Messages" of a system that has four processes, P_1, P_2, P_3, and P_4. With the help of diagrams, explain clearly what the process would do in each of the following cases.

   a) The current vector time of Process P_3 was $\mathbf{C_3}$ when it recieved a message from P_2 along with vector time stamp $\mathbf{t_m}$, where

   $$\mathbf{C_3} = \begin{pmatrix} 1 \\ 2 \\ 3 \\ 1 \end{pmatrix} \qquad \mathbf{t_m} = \begin{pmatrix} 1 \\ 3 \\ 3 \\ 1 \end{pmatrix}$$

   Should P_3 deliver the message immediately? Why? If not, what should it do?

   b) Process P_2 with current vector time $\mathbf{C_2}$ recieved a message from P_1 along with vector time stamp $\mathbf{t_m}$, where

   $$\mathbf{C_2} = \begin{pmatrix} 1 \\ 2 \\ 3 \\ 4 \end{pmatrix} \qquad \mathbf{t_m} = \begin{pmatrix} 2 \\ 2 \\ 3 \\ 5 \end{pmatrix}$$

   Should P_2 deliver the message immediately? Why? If not, what should it do?

(Indexing from 1 rather than 0, C2[1] refers to the 1st entry in C2.)

a, Should P3 deliver the message immediately? Why? If not, what should it do?

Yes. C3[i] = tm[i] for all i except 2, meaning every message P2 has received up to the point of when the message was sent was received by P3.

Additionally, C3[2] = tm[2] – 1, meaning that P3 received every message sent by P2 up to this point.

These two factors combined means it's time to deliver the message.

b, Should P2 deliver the message immediately? Why? If not, what should it do?

It should not.

C2[1] = tm[1] -1, meaning P2 has received every message from P1 before this, so this condition is satisfied.

But C2[4] != tm[4], specifically, C2[4] = tm[4] – 1, meaning at the time the message was sent, P1 received 1 message from P4 that, at the present time, P2 hasn't yet seen.

Because of that, what P2 needs to do is to wait for the message from P4 to arrive before delivering this message. (That message might trigger other waits if P4 had seen messages at time of sending that P2 hadn't.)

2, (10 Points)

2. Consider a cut $\mathbf{C}$:

$$\mathbf{C} = \begin{pmatrix} c_1 \\ c_2 \\ c_3 \end{pmatrix}$$

where c_1, c_2, and c_3 are the cut events with vector clocks $\mathbf{C_1}, \mathbf{C_2}, \mathbf{C_3}$ respectively:

$$\mathbf{C_1} = \begin{pmatrix} 1 \\ 0 \\ 1 \end{pmatrix} \qquad \mathbf{C_2} = \begin{pmatrix} 2 \\ 2 \\ 0 \end{pmatrix} \qquad \mathbf{C_3} = \begin{pmatrix} 0 \\ 1 \\ 3 \end{pmatrix}$$

Calculate $T_C = sup(C_1, C_2, C_3)$. Is $\mathbf{C}$ a consistemt cut? Why?

No.

C2[1] > C1[1], meaning C2 received a message that C1 hasn't sent it.

More formally:

T = sup(C1, C2, C3) = {2, 2, 3}.

But T[1] > C1[1]. So the cut isn't consistent.

Sup(C1, C2, C3) needed to equal {C1[1], C2[2], C3[3]}, but that equals {1, 2, 3} not {2, 2, 3}.

C[2][1] > C[1][1], meaning C2 happened after C1.

3, (10 Points assumed)

3. A banking system uses Chandy-Lamport global state recording protocol (Snapshot Algorithm) to record its global state; markers are sent along channels where FIFO is assumed. The system has three branches P_1, P_2, and P_3 and are connected by communication channels C_{ij}, where $i, j = 1, 2, 3$. Suppose LS_i denote the local state (the money the branch possesses at the time of recording) of branch P_i.

   P_1 initiated the recording process. Right before P_1 sent out the marker, a \$1 transaction was in transit on C_{12}, a \$2 transit on C_{21}, a \$3 transit on C_{23}, and a \$10 transit on C_{31} (assume that the units are in million dollars) and branches P_1, P_2, and P_3 had \$40, \$50, and \$60 respectively (not including any money in transit). Assume that the branches do not send out any other money during the whole recording process and the markers from P_1 arrived at other banks earlier than other markers. With the help of diagrams, find out the state LS_i of P_i and channel states C_{ij} where i, j = 1, 2, 3. Tabulate your results in the following format:

State	Money
LS_1	..
LS_2	..
LS_3	..
C_{12}	..
C_{13}	..
C_{21}	..
C_{23}	..
C_{31}	..
C_{32}	..

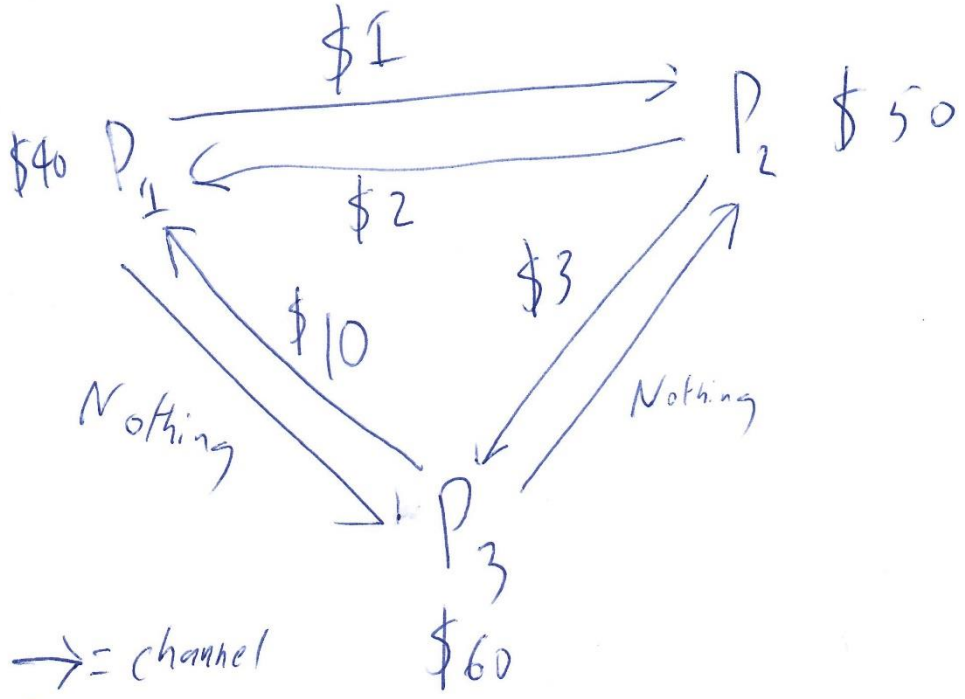
Show your steps clearly.

Assuming C12 denotes the channel P1 uses to send messages to P2. Also assuming that a \$1 transaction in transit on C12 means that \$1 was already deducted from P1 but not yet added to P2.

That is, the total money in the system = P1 + P2 + P3 + Money in transit.

Also assuming that markers will be treated as regular transactions in terms of how they move in a communication channel. (That is, a marker sent after a transaction in the same channel will arrive after that transaction. E.x. the \$1 in C12 will arrive before the initial marker P1 sends to P2.)

Additionally, assuming that processes do not keep track of messages sent before they started recording state. (I.e. the branches don't know of the money currently in transit.) Also, markers being received are not saved in local states. (That is, local states don't treat markers received as messages received, so they don't record them as something in a channel.)



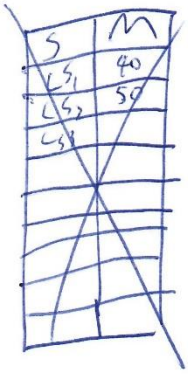
→ = channel

P_i = Branch i

Total money = 40 + 50 + 60 + 1 + 2 + 3 + 10

= 166

Step 1: P_1 records local state, sends marker through C_{12}, C_{13}.



Step 1 state:

State	Money & Marker(s)
LS1	40
LS2	Not Yet Recorded (50)
LS3	Not Yet Recorded (60)
C12	1, Marker
C13	None (0), Marker
C21	2
C23	3
C31	10
C32	None (0)

At step 1, C12 contains $1 and a marker from P1.

C13 contains a marker from P1.

C21 contains $2.

C23 contains $3.

C31 contains $10.

C32 contains nothing.

The P1 marker contains the fact that it has $40. (But not the fact that it sent $1 on the channel C12.)

Step 2 State:

We will process things in terms of markers. That is, we will assume money in transit stays in transit until a marker is sent in the channel. Because of FIFO, the marker will need to wait for the money to be processed before being processed itself.

The marker from P1 arrives. C13 was empty, so P3 receives only the marker. C12 on the other hand contained $1, so P2 receives $1 before receiving the token.

Consequently, when P3 records its own state it recorded itself has having $60, and C13 as empty. It then sent out markers containing this fact through C31 and C32.

However, when P2 recorded its own state it recorded itself as having $51, and C12 as empty. (C12 is treated as empty because the money from C12 arrived before the marker.)

After this is done, P2 sends its marker ($51, C12 & C32 empty) through C21 and C23.

P3 sends its marker ($60, C13 and C23 empty) through C31 and C32.

State	Money & Marker(s)
LS1	40
LS2	51, C12 Empty
LS3	60, C13 Empty
C12	None (0)
C13	None (0)
C21	2, LS2 Marker
C23	3, LS2 Marker
C31	10, LS3 Marker
C32	None (0), LS3 Marker

Step 3 State:

At P1, the money from P2 and P3 arrives at P1 before the markers, then the markers arrive.

At P2, the marker from P3 arrives.

At P3, the money from P2 arrives before the marker from P2.

Consequently, P1 records C21 as containing $2, and C31 as containing $10. LS1 is now: $40, C21 $2, C31 $10. (That is, P1 has $40, C21 had $2 in transit, and C31 had $10 in transit.) P1's cash isn't updated because this is a snapshot.

P2 receives a marker from P3, LS2 had been recorded, but it didn't see a message before seeing the marker, consequently C32 is recorded as empty. LS2 is now $51, C12 empty (known from before), C32 empty.

P3 receives the money ($3) from C23, then the marker from P2. Because LS3 had been recorded, LS3 records C23 as containing $3. LS3 is now $60, C13 empty, C23 $3.

State after all markers have been received.

State	Money & Marker(s)
LS1	40, C21 $2, C31 $10
LS2	51, C12 empty, C32 empty
LS3	60, C13 empty, C23 $3
C12	None (0)
C13	None (0)

C21	None (0)
C23	None (0)
C31	None (0)
C32	None (0)

Final state after assembling all local states. (LS1, LS2, and LS3 are combined to form this.)

State	Money
LS1	40
LS2	51
LS3	60
C12	None (0)
C13	None (0)
C21	2
C23	3
C31	10
C32	None (0)

^Above is the answer to this problem.

The snapshot shows $40 at P1, $51 at P2, $60 at P3, C21 as having had $2 in transit, C23 as having had $3 in transit, and C31 as having had $10 in transit.

The other channels are empty.

4, (10 points assumed)

4. In Lamport's algorithm for mutual exclusion, Process P_i enters CS when the following 2 conditions are satisfied:

   1) P_i's request is at the head of $requestiqueue_i$
   2) P_i has received a (REPLY) message from every other process time-stamped later than t_{s_i}

   Condition 1) can hold concurrently at several sites. Why then is 1) needed to guarantee mutual exclusion?
   Does the algorithm work if condition 2) is removed? Why? Give an example with illustrations (drawings) to support your argument.

Condition 1) can hold concurrent at several sites. Why then is 1) needed to guarantee mutual exclusion?

Condition 1 is necessary, but not sufficient, for mutual exclusion. That is, if Condition 1 is false then a process very definitely *should not* enter the critical section, because another process is

very likely to be inside the critical section if a different process is at the head of a queue. There will be instants of time after a process leaves the critical section but before its RELEASE message arrives at other processes where the process at the head of queue isn't inside the CS, but to guarantee only 1 process is inside the critical section at a time every process needs to assume the process at the head of the queue is inside the critical section. Consequently, processes not at the heads of their own queues must not enter the critical section.

That is, only those processes at the head of their queues should be inside critical sections, but not all processes at head of queues should be inside critical sections. However, if a process is not at the head of its own queue, then it definitely *shouldn't* be inside a critical section.

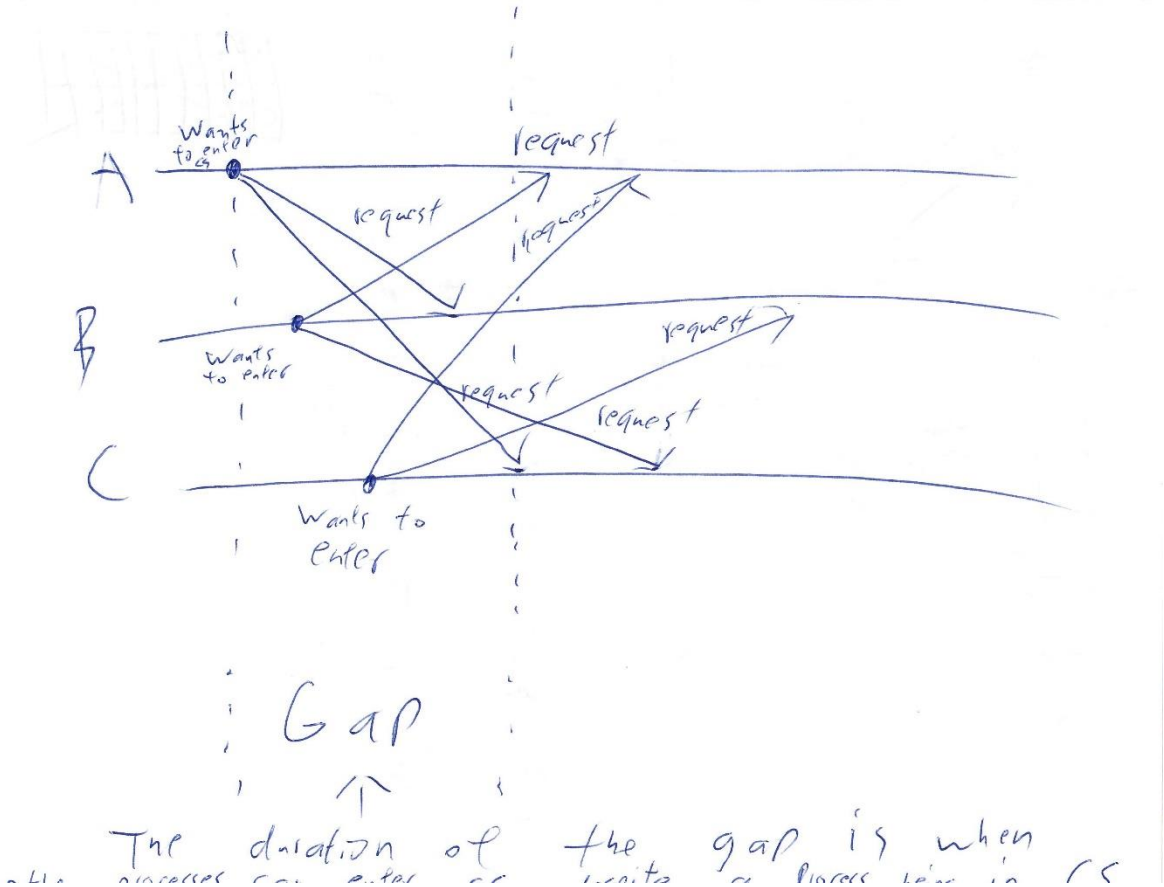
Hence the requirement.

Does the algorithm work if condition 2) is removed? Why? Give an example with illustrations to support your argument.

No.

As stated above, multiple processes can be at the head of their queues at the same time, consequently, if condition 2 is removed, multiple processes might enter the critical section.

This is because of the delay during the time a process sends out its request to enter the critical section and when its received by other processes. Consequently, if multiple processes sends out the request at similar times then they might all be at the head of their own request queues. Without acknowledgement from other processes there's no way to know if a process slipped through the 'gap' between when it sends out its own request to enter the critical section and when the request from another process that wishes to enter the critical section arrives.



As pictured, the gap is the duration of time where another process can enter the critical section despite a process already being inside the critical section. To avoid this gap, condition 2) is necessary.

Note how despite the fact that A entered the critical section and sent out messages saying so, B and C would also be able to enter the critical section if rule 2) isn't applied.

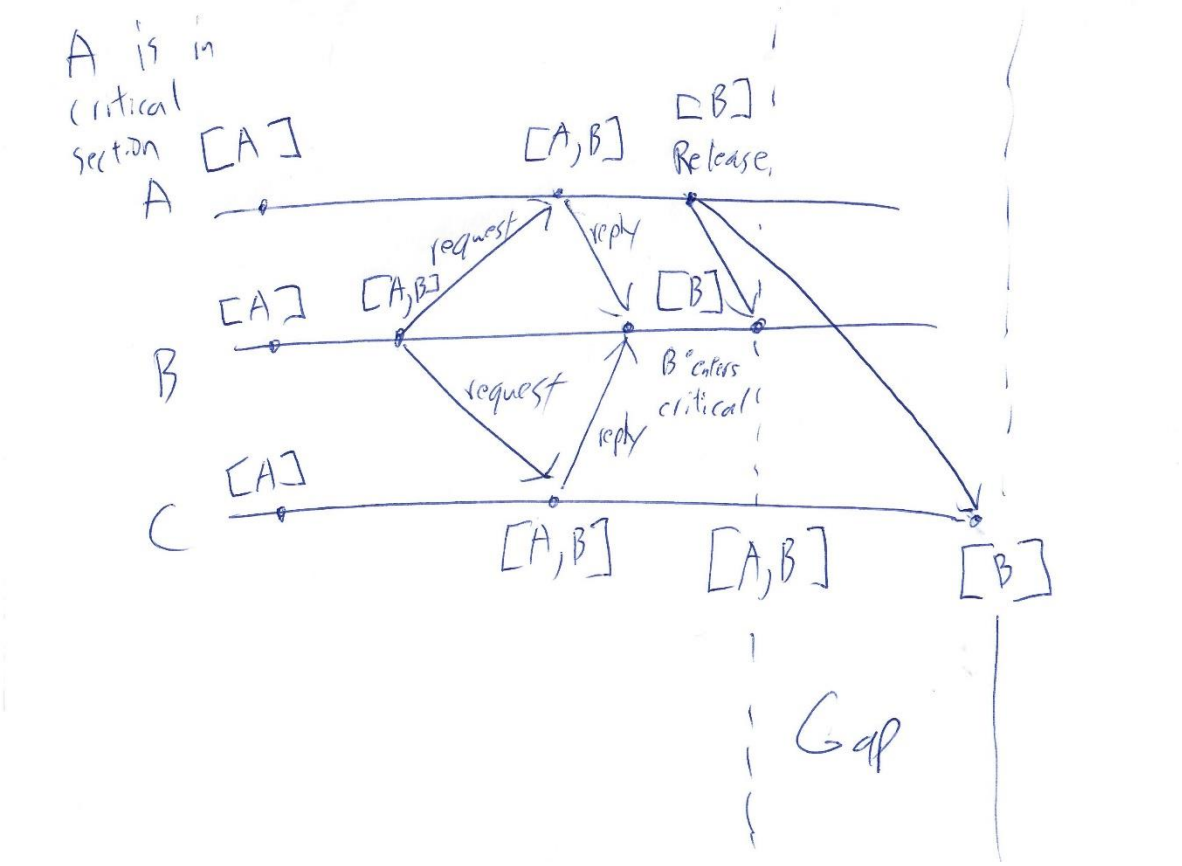
This is assuming the request queue is empty for all three processes at the start of the diagram.

5,

5. In Lamport's algorithm of mutual exclusion, if a site S_i is executing the critical section, is it necessary that S_i's request need to be **always** at the top of the request-queue at another site S_j? Explain and give an example (with diagrams) to support your argument.

It's not necessary. This is because of the delay in the RELEASE message being sent out and the RELEASE message arriving at other processes.

Specifically, the delay isn't constant, so one process might receive the RELEASE message, and update its own request queue, before other processes.



As you can see, because of the difference in time for the RELEASE message to arrive at process B and process C, there is a gap in time where B is permitted to enter the critical section (received replies from all processes, head of its own queue), yet in process C, the request queue contains a different process at the head of the queue.