Homework 1

CS425/ECE428 Spring 2019

Due: Thursday, Feb 7 at 11:55 p.m.

1. (a) (3 points) Consider an asynchronous distributed system with unbounded message delay (though guaranteed message delivery), and perfectly synchronized clocks. p_i and p_j implement a heartbeat protocol, where p_j sends a heartbeat every T time units, and p_i declares p_j as failed when it does not hear a heartbeat for $T + \Delta$ time units. What is the worst-case detection time for p_j having failed? (*Hint:* it will depend on the number of heartbeats sent.)

   (b) (2 points) Can you suggest a modification to the protocol to make the worst-case detection time bounded regardless of the number of heartbeats?

   (c) (4 points) Consider N processes using a ring ping-ack protocol. (I.e., p_i sends a ping to p_{i+1} who sends an acknowledgment back.) Pings are sent every T time units, and a timeout is set to Δ. Assume again we are in an asynchronous network, and let the probability that a round-trip time exceeds Δ be p.

   What is the probability that at least one alive process will be declared as having failed within a time period T? Calculate the value for $p = 0.01$ and $N = 100$.

   What if we declare failure only after k missed acks?

   (d) (2 points) Consider a ping-ack protocol in a *synchronous* network with a minimum one-way delay of 10 ms and a maximum delay of 100 ms. Let $T = 1$ s and assume no processing delays and perfectly synchronized clocks.

   What should your timeout value be? What is the maximum detection time?

2. (a) (6 points) Consider a hierarchical NTP synchronization between four processes, A, B, C, and D as shown in Figure 1a. Each arrow is labeled with the *round-trip delay* betwen two processes. What is the bound on the clock skew between every pair of processes?

   (b) (4 points) Consider a maximum drift rate of 0.01%. How frequent should *each* synchronization be to ensure that no two processes have a skew larger than 50 ms?

   (c) (2 points) Suppose that there was a flat hierarchy instead where B,C, and D all synchronized with A, with an RTT of 50ms, as shown in Figure 1b. What would be the clock skew between every pair of processes?

3. (a) (5 points) Looking at fig. 2, write down the Lamport timestamp of each event.

   (b) (5 points) Using fig. 2, write down the vector timestamp for each event

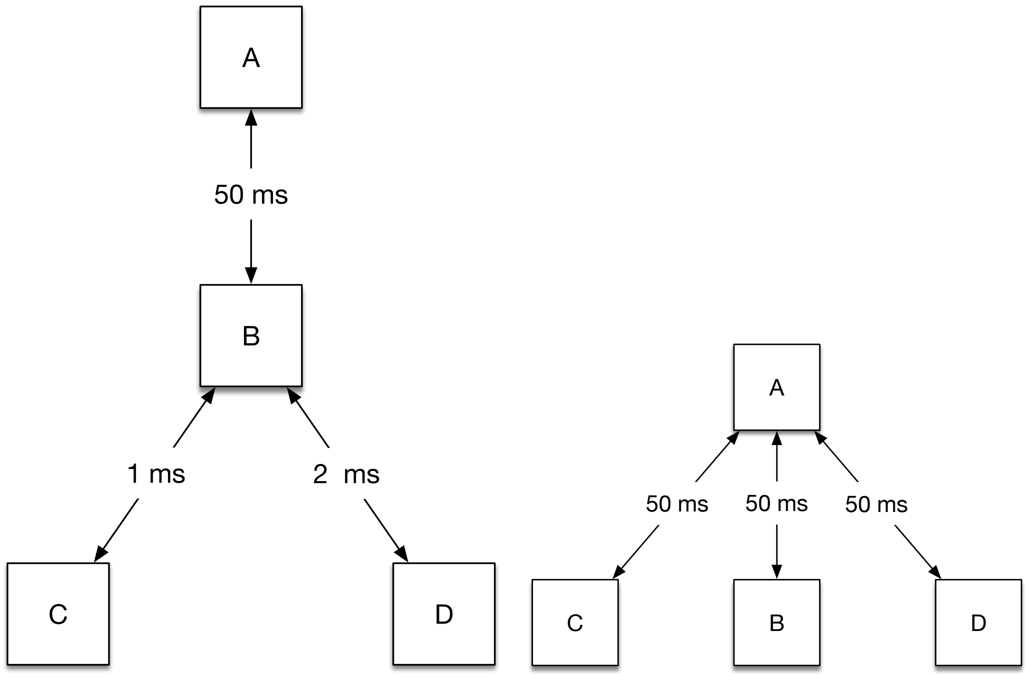
   (c) (5 points) List all the concurrent events

4. (a) (4 points) Looking at fig. 2, suppose that P1 initiates the Chandy-Lamport snapshot algorithm at time 9. Write down *all* possible consistent cuts that the resulting snapshot could capture. (You can describe each cut by its frontier events.)

   (b) (4 points) Pick an example of a distributed system; feel free to use some of the ones previously mentioned in class. Give one example of each of the following in that system:

   - A stable property
   - An unstable property
   - A liveness property
   - A safety property

   You may use the same system for all properties or several different ones.



(a) NTP configuration for part a.

(b) NTP configuration for part c.

Figure 1: NTP configuration for Question 2

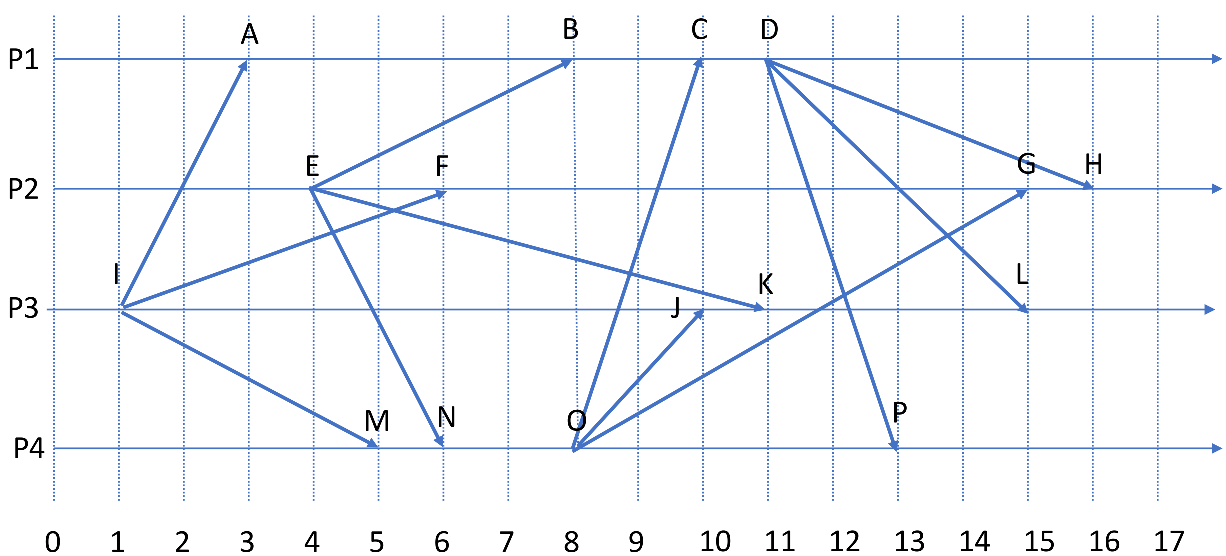


Figure 2: Timeline for questions 3 and 4.