**Rules:**

- **You are not allowed to use books, notes, or other material.**
- **You can answer in Italian or English.**
- **Total time for the test: 2 hours.**

1. Describe Remote Procedure Call in general and the various architectural issues that characterize this model of communication (e.g., parameter passing, client/server binding, synchrony, …)

2. Describe the different protocols you know to synchronize clocks in a distributed system.

3. Calculate the recovery line for the two diagrams below using the rollback-dependency graph for the first one, and the checkpoint dependency graph for the second one. Finally, briefly describe when we build such diagrams, how we build them, and the general goal this algorithm solves.
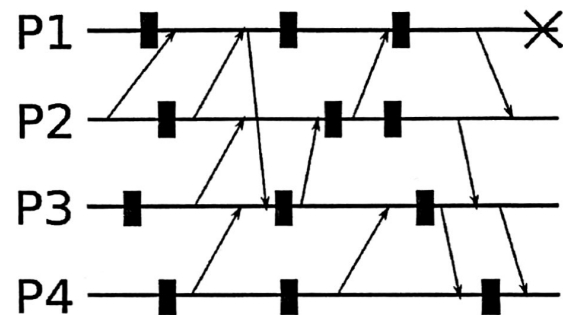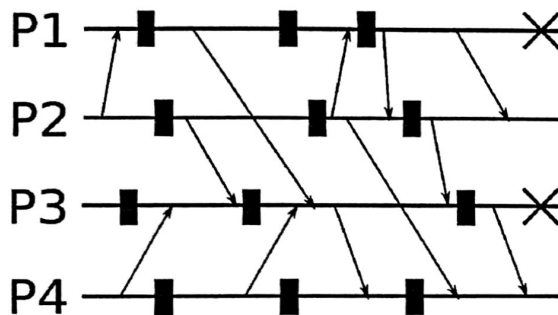
4. Describe the Lamport's protocol to guarantee totally ordered multicast messaging using scalar clocks (clarify the assumptions you make).

5. a) Consider the following schedule. Is it consistent with respect to the FIFO, causal, sequential consistency models? Motivate your answers.

P0	W(x) 1	R(y) 2	W(x) 3	R(y) 4
P1	W(y) 2	R(x) 3	W(y) 4	
P2	R(y) 2	R(x) 1	R(x) 3	R(y) 4

b) Now assume that all the operations are performed on the same variable x. How does your answer changes?

6. Consider the architecture of a system for processing large volumes of data on a cluster of machines. Define and compare the following design/architectural choices: batched vs streaming, pipelined vs scheduled. In particular, discuss their benefits or limitations in terms of latency, throughput and elasticity.

7. Consider a server for secure group communication using the centralized flat table and supporting up to 8 members. The following members are currently connected: 1, 2, 3, 4, 7

   a) Describe the state of the server and the clients: the current table for the server and the set of keys for each client.

   b) Now assume that member 5 joins and member 4 leaves. For each of the two operations, describe which keys have to be revoked and which keys have to be (re)generated.