**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.**

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1. Describe the REST architectural style.

2. Describe name resolution in general and focus on the various approaches you know to resolve flat names.

3. Calculate the recovery line for the two diagrams below using the rollback-dependency graph for the first one, the checkpoint dependency graph for the second one.
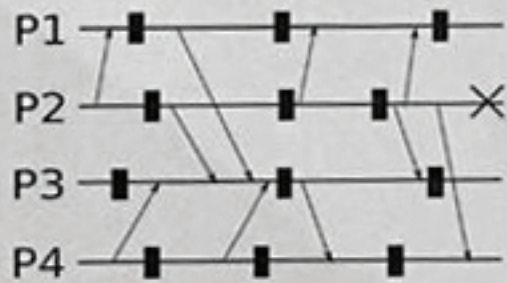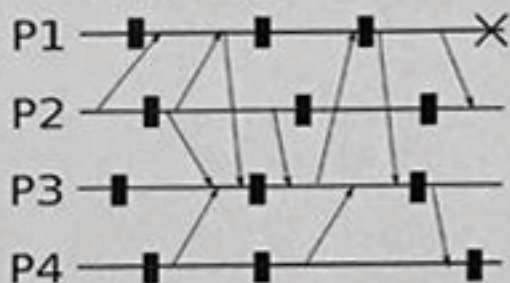
4. Describe leader election protocols and compare them in terms of assumptions and number of messages required to end the election.

5. Consider the following schedule of processes that access a replicated data store.

P0	W(x) 1	R(x) 2	W(x) 3
P1	R(x) 1	W(x) 2	W(x) 4
P2	R(x) 3	W(x) 5	R(x) 4
P3	R(x) K	R(x) ?	R(x) 5

Depending on the value of K, which values can the second read of P3 return in the case of a FIFO, causal, or sequential consistency model? Motivate your answer.

K=2	FIFO	
K=2	Causal	
K=2	Sequential	
K=3	FIFO	
K=3	Causal	
K=3	Sequential	

6. Consider the MapReduce programming model and execution framework:
   a) Explain the programming primitives that the model offers.
   b) Exemplify these programming primitives using a word-count application that takes in input some documents and outputs the number of occurrences of each word appearing in the documents.
   c) Explain how the execution framework handles data parallelism, data locality, fault tolerance, and stragglers.

7. Describe the following three approaches for search/lookup in a P2P network:
   - centralized table (e.g., Napster),
   - flooding (e.g., Gnutella),
   - Distributed Hash Table (DHT – e.g., Chord).

   Compare them in terms of state maintained at each node, search expressivity, search scope, guarantees of lookup success, resilience to network dynamicity (joins and leaves of nodes).