Assignment 1: Agreement and Two Generals Paradox (1 P.)

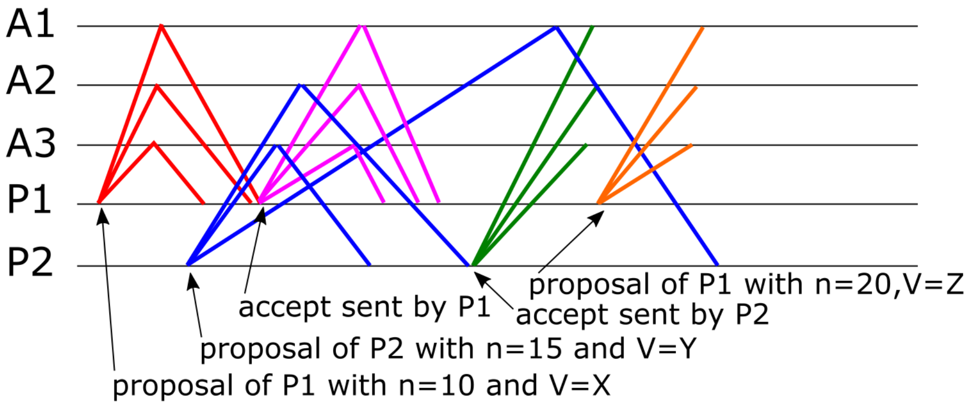
(a) Argue that agreement under Byzantine failures can be reached for three "generals", with one of them faulty, if the generals digitally sign their messages. For simplicity, work with the scenarios α_1, α_2, and α_3 shown on the lecture slides.

(b) To find a practical solution to the two army problem, the generals come up with the idea that it is good enough to make sure with high probability that at least one messenger out of n messengers sent makes it through the enemy lines in order to deliver the message. Assume that the risk that a messenger gets through is p (can be modeled by a Bernoulli random variable). How many messengers does a general need to send in order to know that at least one gets through with probability of at least θ? Hint: Use Hoeffding's inequality to analytically derive your answer.

How large is n for $p = 0.1$, $p = 0.5$, or $p = 0.9$, for $\theta = 0.9$ or $\theta = 0.999$?

Assignment 2: Consensus with Paxos (1 P.)

(a) Given the communication across two proposers (i.e., P_1 and P_2) and three acceptors (i.e., A_1, A_2, and A_3), depicted in the following illustration. First, describe how Paxos acts in each of these communications indicated, and what is the state of the acceptors after each received message. Then, explain a possible way the Paxos consensus algorithm, as described in the lecture, proceeds in this situation (i.e., how the accept and propose messages of P2, respectively, P1 are handled. The horizontal lines represent the evolving time. Assume that in the beginning the acceptors did not see or accept any proposal.



(b) For each of the following states of Paxos acceptors, verify if this state can happen when having at least two proposers and the starting state of the acceptors is to have no value chosen. If not, explain why this state cannot happen. If yes, write an explicit example of communication between the introduced proposers and the three acceptors that leads to this state.

Scenario 1:

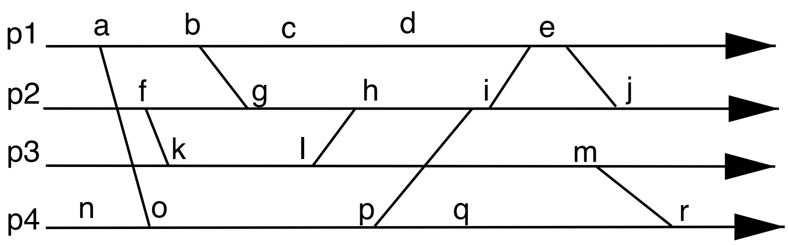
A_1	A_2	A_3
$Np = 5$	$Np = 5$	$Np = 6$
$Na = 5$	$Na = 5$	$Na = 6$
$Va = X$	$Va = X$	$Va = Y$

Scenario 2:

A_1	A_2	A_3
$Np = 5$	$Np = 6$	$Np = 7$
$Na = 5$	$Na = 6$	$Na = 6$
$Va = X$	$Va = Y$	$Va = Y$

Assignment 3: Lamport Timestamps (1 P.)

Consider processes p_1, p_2, p_3, and p_4 with associated events $a, \ldots, r$ and interchanged messages as shown in the figure:



(a) Which events are not related by the happened-before relation, i.e., are concurrent to the a, f, l, and i events?

(b) Assume each process maintains a local logical clock. Assign to each event a timestamp according to Lamport's algorithm.