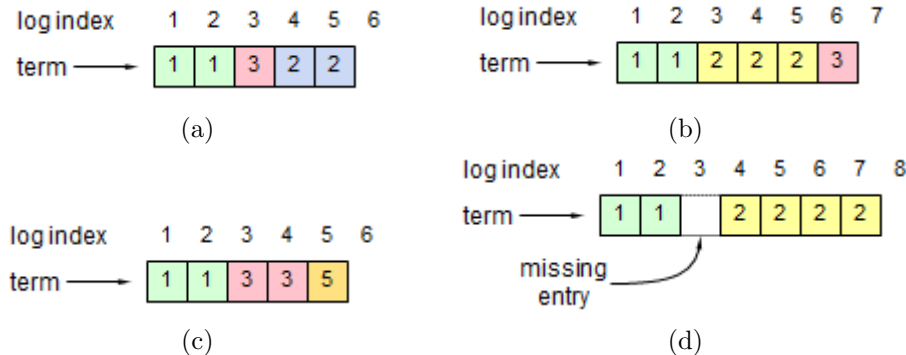


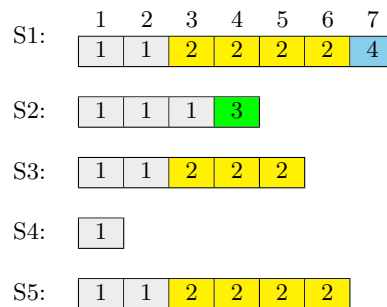
All questions are based on Ongario and Ousterhout's Raft user study.

- Each figure below shows a possible log configuration for a Raft server (the contents of log entries are not shown; just their indexes and terms). Considering each log in isolation, could that log configuration occur in a proper implementation of Raft? If the answer is "no," explain why not.

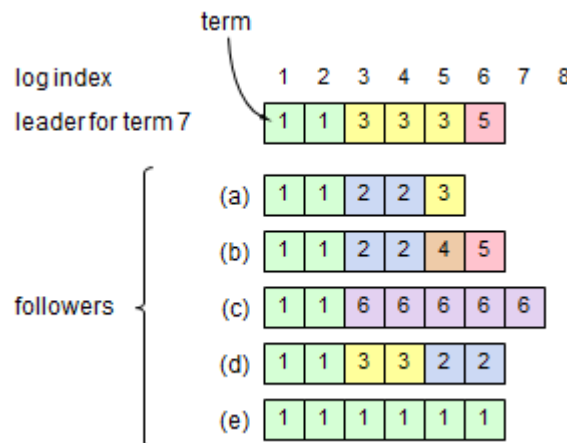


- The figure below shows the state of the logs in a cluster of 5 servers (the contents of log entries are not shown; just their indexes and terms) where the current leader is S1.

- Which of the servers could be elected as the new leader if S1 were to fail?
- Which log entries may safely be applied to the state machines?



- Consider the figure below, which displays the logs in a cluster of 6 servers just after a new leader has just been elected for term 7 (the contents of log entries are not shown; just their indexes and terms). For each of the followers in the figure, could the given log configuration occur in a properly functioning Raft system? If yes, describe how this could happen; if no, explain why it could not happen.



4. Suppose that a hardware or software error corrupts the `nextIndex` value stored by the leader for a particular follower. Could this compromise the safety of the system? Explain your answer briefly.
5. Suppose that you implemented Raft and deployed it with all servers in the same datacenter. Now suppose that you were going to deploy the system with each server in a different datacenter, spread over the world. What changes would you need to make, if any, in the wide-area version of Raft compared to the single-datacenter version, and why?
6. Recall that each server stores three pieces of information on its disk: its current term, its most recent vote, and all of the log entries it has accepted.
  - (a) Suppose that a follower  $F$  crashes, and when  $F$  restarts, its most recent vote has been lost. Is it safe for  $F$  to rejoin the cluster (assuming no modifications to the algorithm)? Explain your answer.
  - (b) Now suppose that a follower  $F$ 's log is truncated during a crash, losing some of the entries at the end. Is it safe for  $F$  to rejoin the cluster (assuming no modifications to the algorithm)? Explain your answer.
7. It is possible for a leader to continue operating even after other servers have decided that it crashed and elected a new leader. The new leader will have contacted a majority of the cluster and updated their terms, so the old leader will step down as soon as it communicates with any of these servers. However, in the meantime it can continue to act as leader and issue requests to followers that have not yet been contacted by the new leader; furthermore, clients may continue to send requests to the old leader. We know that the old leader cannot commit any new log entries it receives after the election has completed, since it would need to contact at least one of the servers in the electing majority to do this. But, is it possible for an old leader to execute a successful `AppendEntries` RPC that completes the commitment of an old log entry that was received before the election started? If so, explain how this could happen, and discuss whether or not this will cause problems for the Raft protocol. If this cannot happen, explain why.